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MISSION ASSURANCE REQUIREMENTS
FOR THE
OZONE MONITORING INSTRUMENT

OCTOBER 1999

NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771

MISSION ASSURANCE REQUIREMENTS
FOR THE
OZONE MONITORING INSTRUMENT (OMI)
FOR THE
EOS CHEMISTRY MISSION

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SECTION 1

OVERALL REQUIREMENTS

1.0 OVERVIEW

This document defines the mission assurance requirements for the OMI instrument. The Netherlands Agency for Aerospace Programs (NIVR) is required to plan and implement an organized safety, reliability and mission assurance program that encompasses all flight hardware, software and ground support equipment. This program is required through launch operations up to and including spacecraft commissioning. NIVR shall support and participate with the EOS Chemistry Project in validating and periodically reviewing the safety, reliability and mission assurance program.

Hardware and/or software that was designed, fabricated, or flown on a previous program, may be considered to have demonstrated compliance with some or all of the requirements of this document such that certain tasks need not be repeated. When this is proposed, NIVR is required to demonstrate how the hardware and/or software complies with the requirements.

SECTION 2

VERIFICATION

2.0 MISSION ASSURANCE

2.1 Quality System

NIVR shall define and implement a quality system that meets the intent of ISO 9001. NIVR's quality system shall properly encompass all OMI instrument flight hardware, flight software, and ground support equipment. It is expected that the ECSS-Q and/or PSS-01 series shall be followed for OMI Product Assurance. An OMI Instrument Performance Verification Plan (DRL 022) shall be provided for GSFC review.

2.2 Workmanship

NIVR and their contractors must inform GSFC how they comply with ESA and/or NASA design and workmanship standards. The following NASA workmanship standards could be used for the mission if desired. ESA or NIVR internal workmanship standards may be utilized if they meet the intent of the following standards.

Soldering Electrical Connections: NASA-STD-8739.3; *Soldered Electrical Connections.*
Alternate: J-STD-001B Class 3 with addendum's to provide for training and low volume, high reliability flight hardware.

Crimping, Interconnecting Cables, Harnesses, and Wiring: NASA-STD-8739.4

Conformal Coating and Staking: NAS 5300.4(3J-1), *Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies*

ESD Control: NASA-STD-8739.7; *Electrostatic Discharge Control (Excluding Electrically Initiated Explosive Devices).*

Surface Mount Technology (SMT): NAS 5300.4 (3M), *Workmanship Standard for Surface Mount Technology.*
Note: SMT processes must be qualified to the mission profile and life expectancy.

2.3 Product Verification

The work activities, operations, and documentation performed by NIVR or their contractors are subject to evaluation, review, and inspection by government-designated representatives from GSFC. NIVR, upon request, shall provide government quality assurance representatives with documents, records, and equipment required in performing their assurance and safety activities. GSFC requests a representative sample populated printed wiring board be provided to GSFC for evaluation and comment. Detailed analysis of the results will be provided to NIVR.

NIVR must ensure that hardware and software products meet ESA and/or NASA standards.

2.4 Failure Reporting

A problem/failure report shall be written for any departure from design, performance, testing, or handling requirement that affects the function of flight equipment, ground support equipment that interfaces with flight equipment, or that could compromise instrument objectives.

Reporting of failures to the Chemistry Project Office along with NIVR approval of corrective action shall begin with the pre and post instrument integration activities at the instrument level (Reference DRL 209). For software problems, failure reporting shall begin with the first test use of the software item with the hardware item. NIVR can use any failure report format they deem acceptable, as long as the Project office has concurred with their format.

In addition, NIVR shall maintain failure-reporting records of problems encountered at the lower levels of assembly for information, tracability, and trending analysis. These records should be available for GSFC inspection at any time during the mission on a non-interference basis.

SECTION 3

DESIGN REVIEWS

3.0 REVIEWS

The Project office philosophy is to focus resources early and throughout the program on technical working level reviews to identify and resolve concerns before these issues reach formal, high level system reviews. NIVR or its delegated representative is responsible for conducting technical peer reviews. Upon request through the Project, GSFC will provide technical expertise as required for participation and potential support in the areas undergoing detailed technical review.

The formal system level reviews will concentrate on the interfaces, critical system and end to end mission level technical and programmatic issues. These reviews should include discussions of flight hardware, flight software, and ground systems that interface with flight hardware. The Project office recommends that software reviews be one phase ahead of hardware development to mitigate risk. For each review, an agenda, and a review data package shall be provided to GSFC 20 working days prior to the scheduled review. There will be four formal instrument system level reviews:

- Preliminary Design Review
- Critical Design Review
- Pre-Environmental Review/Technical Readiness Review
- Pre-Ship Review/Delivery Review

These formal reviews shall be co-chaired with NIVR and the GSFC Office of Systems Safety and Mission Assurance (OSSMA), Systems Review Office, Code 301. Scheduling of these reviews shall be coordinated with the Project. The review chairpersons appoint independent key technical experts as review team members. Every effort will be made to maintain the chairpersons and the key technical experts for the duration of the Project. Other experts will be added and/or deleted from the review team according to the technical needs and phases of the instrument. Attachment A, Code 301 Design Review Guidelines provides additional details on expected review content.

3.1 Formal Reviews

Preliminary Design Review (PDR) – (Reference DRL 016) This review occurs early in the design phase, but prior to manufacture of engineering hardware and the detail design of associated software. Where applicable, it should include the results of test bedding, breadboard testing, and software prototyping. Long-lead procurements shall be discussed.

Critical Design Review (CDR) – (reference DRL 020) This review occurs after the design has been completed but prior to the start of manufacturing flight components or the coding of software. It shall emphasize implementations of design approaches as well as test plans for flight systems including the results of engineering model testing.

Pre-Environmental Review (PER)/Technical Readiness Review(TRR) – (Reference DRL 029) This review assesses the readiness of the flight hardware, software and required environmental test facilities to begin acceptance testing. The PER will be held prior to formal functional test of the OMI instrument. The PER will also cover:

- design changes since CDR
- status of nonconformances
- test documentation (plans, procedures, waivers) and facilities readiness
- hardware and software configuration
- mission operations status
- Qualification status

The purpose of this review is to satisfy the review board that the hardware and software procedures and processes are ready and in place to start the environment testing and that the tests can be conducted in a safe manner without danger or damage to personnel, facilities and test articles. Software requirements must all be met with all action items closed, and most acceptance tests done. Software should be essentially flight ready.

This review shall examine details of the test plans and procedures and verify that final plans for each test to be conducted are complete. This review shall delineate the overall test philosophy and the management and organization of the tests including interactions with the program assurance personnel. This review shall identify by name the test conductor, test coordinator, facilities coordinator and any other personnel having the ability to start and stop tests.

Pre-Ship Review (PSR)/Delivery Review (DR) – (Reference DRL 032) This review will verify that testing has been completed with no unacceptable open issues and to evaluate the readiness of the flight hardware and flight software. The PSR will be held immediately prior to the shipment of the flight hardware to the spacecraft. The PSR will also cover as a minimum:

- determination the completion of testing flight hardware and software
- verification and documentation of hardware and software configuration
- identification of outstanding safety risks
- review of all PER action items
- review all instrument level failures or anomalies during test
- review instrument compliance with requirements and specifications
- disposition of waivers, deviations, open issues
- compatibility of instrument with ground support equipment, spacecraft integration, and the launch site
- evaluation of the end-item acceptance data package

SECTION 4

SAFETY

4.0 OVERVIEW

NIVR, with GSFC support is responsible for the overall safety of the instrument and personnel, from start of development through launch. In fulfilling this responsibility, NIVR is required to establish a comprehensive safety program. This includes documenting hazard analyses, hazard reports, and operations hazards analyses in safety data packages (Reference DRL 107,224,225,406).

4.1 General

NIVR is required to produce a System Safety Compliance Data Package in accordance with DRL 224 that accomplishes the following:

- Identifies and controls hazards to personnel, facilities, support equipment, and the flight system during all stages of the mission development. The program is to address hazards in the flight hardware, associated software and ground support equipment. MIL-STD-882C may be used for guidance.

- Meets the system safety requirements stated in EWR 127-1(T) for the Western Range.

NIVR is required to provide a description of the system down to the subsystem level, and a preliminary assessment of the system's compliance with the requirements of this section at the CDR. A final assessment is due 120 days prior to PSR.

4.2 Safety Data Package

NIVR shall provide inputs to the spacecraft team in order to develop the Missile System Prelaunch Safety Package (MSPSP). The contents of the MSPSP will be consistent with the requirements in EWR 127-1, Appendix 3A. A preliminary Safety package is due at CDR, an update at PER, and a final 90 days prior to the PSR. (Reference DRL 224 and 225)

4.2.1

All hazards and risks associated with the Mission will be identified at a system and subsystem level. All hazards identified will be controlled through engineering design, operational controls and procedures, and/or personnel controls. Hazard analysis tools used to identify and control hazards can include preliminary hazard analyses (PHA), system/subsystem hazard analyses (SHA/SSHA), operational hazard analyses (OHA), failure modes and effects analyses (FMEA), and risk assessment.

NIVR is required to work with the S/C contractor to develop verification steps to ensure all measures are taken to implement hazard control methods for the Instrument.

As an input to the MSPSP, NIVR shall detail the instrument ground operations planned for the processing flow at the launch site. This shall include a description of all GSE to be used, testing, and hazardous operations.

4.2.2

When any specific safety requirement cannot be met, NIVR shall develop an associated Safety Noncompliance Request (SNR) that identifies the hazard and shows the rationale for approval of a noncompliance, as defined in EWR 127-1, Appendix 6B. NIVR will submit the noncompliance request to the GSFC Project Safety Manager (PSM) for review prior to submittal to the Range for approval.

4.3 Procedures

NIVR is required to submit, in accordance with an agreed-to schedule in the Joint Project Implementation Plan, all ground operations procedures to be used at GSFC facilities, other NASA integration facilities, or the launch site, for review and approval by NASA. All of the launch site procedures are to be submitted to GSFC and will be forwarded to KSC NASA/Range Safety for review and approval. All hazardous procedures that will be performed at the launch site are to be identified in the MSPSP. All launch site procedures are to comply with the applicable launch site safety regulations contained in EWR 127.1(T), Appendix 6B.

5.0 DESIGN ASSURANCE

5.1 Parts

NIVR shall implement a Grade 2 quality level equivalent parts program consistent with meeting the 5-year mission life requirement. Preferred parts are defined in GSFC PPL-21 and MIL-STD-975 as grade 2 and the ESA/SCC series of specifications as level C. GSFC 311-INST-001, entitled "Instructions for EEE Parts Selection, Screening, and Qualification" for Grade 2 quality level is recommended for guidance. NIVR shall control the management, selection, application, evaluation, and acceptance of all parts through a parts control board, or another similar, documented, parts control system. The parts control board (PCB), or system, may be informal. It is recommended that GSFC project parts engineer participate as an active member of the PCB with members of NIVR to determine acceptability of the EEE parts. As a minimum the GSFC Project Parts Engineer and the Netherlands Agency For Aerospace Programs (NIVR)'s part representatives shall be PCB members.

These individuals shall be responsible for the review and approval of all parts for conformance to the GSFC 311-INST-001, Grade 2 quality level or ESA ECC/PPL level C selection criteria. It is suggested that the PCB develop a parts implementation plan to avoid confusion. Under this system, part information is shared between the NIVR and GSFC to identify all parts used, review failure investigations, disposition of non-conformances, and problem resolutions. The PCB is responsible to resolve all parts related issues. Disputes shall be presented to the System Assurance Manager and the OMI Instrument Manager, with documentation of the associated risk, for further action. Unresolved issues shall be elevated to GSFC and NIVR Project Offices for resolution.

NIVR shall maintain an EEE Parts Identification List prior to and during NIVR's hardware build. This as-built list shall be updated and submitted as part of the Acceptance Data Package for the flight instrument (Reference DRL 526).

Destructive Physical Analysis (DPA) will not be required, unless specific issues, such as part failure history, Government Industry Data Exchange Program (GIDEP) Alerts and Problem Advisories, new/unknown technology, or other similar concerns, warrant it. The Parts Control Board shall be responsible for determining which parts, if any, require DPA. DPA completion, when required, shall be in accordance with GSFC S-311-M-70. PIND testing of all cavity devices ESA class C and NASA grade 2 level is recommended in accordance with GSFC 311-INST-001.

All Electrical, Electronic, and Electro-mechanical (EEE) parts shall be derated in accordance with the guidelines specified in ESA PSS 01-301 or GSFC PPL-21, Appendix B. NIVR shall be responsible for the implementation and verification of the derating guidelines.

All EEE parts shall be selected to meet the predicted mission ionizing radiation level requirements, as defined in X-900-93-02, EOS: Common Spacecraft Radiation Environment or ESA PSS-01-609.

5.2 Materials and Lubrication

NIVR shall implement a Materials and Processes program in accordance with ESA PSS-01-70; Materials, Mechanical Parts and Processes. NASA Reference Publication 1124 entitled "Outgassing Data for Selecting Spacecraft Materials" or ESA RD-01, Revision 3, Outgassing and Thermo-optical Data for Spacecraft Materials, may be used as a guide for materials selection on this project. New materials qualification should follow PSS 01-700, 01-701 and 01-702. Only materials that have a total mass loss (TML) <1.00% and a collected volatile condensable mass (CVCM) <0.10% shall be used on this project unless a waiver is submitted and granted by the GSFC Project office. NIVR shall deliver one list that is inclusive of the polymeric materials, inorganic materials, composites, lubricant usage, and the material process utilization. NIVR shall submit this list for GSFC review and comment prior to the Critical Design Review. As part of the project systems engineering team, all proposed materials and processes shall be reviewed with the Chemistry Project Materials Engineer. If there are any materials issues, which NIVR and GSFC cannot resolve at the engineering level, then the GSFC material engineer will inform the System Assurance Manager and the Project Manager of the issue and the associated risk. After this discussion, the project will decide whether to accept the risk and ask NIVR to submit a waiver to document the issue, or to elevate the issue to NIVR's management for resolution.

NIVR shall maintain a list of materials, processes, and appropriate usage records prior to and during the hardware development. This as-built list shall be updated and submitted as part of the Acceptance Data Package (Reference DRL 526) for the flight instrument.

5.3 Reliability

NIVR shall plan and implement a reliability program that interacts with other program disciplines, including systems engineering, hardware design, parts and materials selection, and systems safety. This program shall be conceived and organized to effectively, efficiently, and timely perform tasks that enhance the required mission life time of 5 years, with a goal of 6 years. NIVR shall develop and implement a program reliability plan in accordance with PSS-01-30, Dependability, or NASA Technical Memorandum 4322, Reliability Preferred Practices For Design And Test, that addresses mission objectives, assigns responsibilities, and schedules tasks relative to program milestones. NIVR shall provide a reliability plan to GSFC for review that addresses the following objectives:

I. Design
a) Graceful degradation is a design objective.
b) Reduce series complexity by eliminating unnecessary parts and components.
c) Promote failure workarounds that allow continued successful but degraded operation.
d) By design, wherever practicable, failures shall allow continued successful albeit degraded operation.
e) Isolate failure impact so that effects do not propagate to other functions.
f) Failure of non-critical functions shall not affect critical functions.
g) Show that electrical stress applied to parts and devices meets derating requirements over the extremes of operating temperature range, voltage temperature range, and current variations.
h) Parts meet total dose and single event effects radiation requirements.
i) Verification that a consistent reliability process is flowed down to the Netherlands Agency For Aerospace Programs (NIVR) and suppliers.

II. Manufacture
a) An in-process inspection program that verifies hardware is assembled as designed.
b) A verification program that assures specified manufacturing processes are followed.

III. Test
a) A test program that verifies finished product meets specification.
b) A test program that verifies finished product functions in accordance with the performance specifications.
c) The OMI Instrument must be able to meet Spacecraft test requirements in the EOS Spacecraft Performance Assurance Requirements (PAR), GSFC 420-05-04.

5.4 Software

NIVR shall develop a software management plan (Reference DRL 008) which covers both flight and ground software. Software assurance activities shall also be discussed in this plan and shall be in accordance with ECSS-Q-80A, Software Product Assurance. (Reference DRL's 602,603,604,606,609,610)

NIVR will hold internal software reviews at appropriate times in the program and will notify GSFC as to where and when these reviews will be held. Recommended software reviews are as follows:

- Software Concept Review
- Software Requirements Review
- Software Preliminary Design Review
- Software Critical Design Review
- Software Test Readiness Review
- Software Acceptance Review

NIVR will report the software design information with the hardware CDR (Reference DRL 020). The software test readiness and acceptance will formally be reported at the PER (Reference DRL 029) and PSR (Reference DRL 032) respectively. By PER, software should be nearly flight ready. It should be tested and used as much as possible.

The corrective action process shall start at the establishment of a Configuration Management baseline that includes the product. In no case shall the use of the formal software corrective action process be delayed beyond the use of the software in hardware for which formal problem reporting is required.

The GSFC shall be allowed access to the problem reports and the corrective action information as they are developed.

NIVR shall establish a Software Configuration Management (SCM) baseline after each formal software review (Reference DRL's 510 and 512). Software products shall be placed under Configuration Management immediately after the successful conclusion of the review. NIVR's SCM system shall have a change classification and impact assessment process that results in Class 1 changes being forwarded to EOS Chemistry project for disposition. Class 1 changes are defined as major changes that affect mission requirements, system safety, changes of more than twenty percent of lines of heritage flight code, reliability, schedule, and external interfaces.

5.4.1 GFE, EXISTING AND PURCHASED SOFTWARE

If NIVR is using existing or purchased software, then NIVR is responsible for the software meeting the functional, performance, and interface requirements placed upon it. NIVR is responsible for ensuring that the software meets all applicable standards, including those for design, code, and documentation. Any significant modification to any piece of the existing software shall be subjected to all of the provisions of NIVR's Software Management Plan and the provisions of this document. A significant modification is defined as a change of twenty percent of the lines of code in the software.

5.4.2 SOFTWARE SAFETY

NIVR shall conduct a software safety program in accordance with or equivalent to NASA-STD-8719.13A with the objective of identifying any safety critical software components. If any software component is identified as safety critical, it must comply with NSS 1740.13 "Software Safety Standard", and Sections 3.16 of EWR 127-1 (Tailored).

6.0 VERIFICATION

NIVR shall conduct a verification program to ensure that the flight hardware and software meets the specified instrument requirements and the GSFC General Instruments Requirements Document (GIRD).

7.0 CONTAMINATION

NIVR shall plan and implement a contamination control program applicable to the mission (Reference DRL 023). The plan shall establish the implementation and describe the methods NIVR will use to measure and maintain the levels of cleanliness required by the GIRD during each of the various phases of the flight hardware's lifetime. The plan shall be in accordance with PSS-01-201, Contamination and Cleanliness Control.

8.0 ACCEPTANCE DATA PACKAGE

The Acceptance Data Package (Reference DRL 526) shall contain the following documents as a minimum:

Approved ICD
As built Parts List
As built Materials List
As built instrument level drawings and complete drawing tree
As built SW documentation and copy of source code
Safety Data Package
List and status of limited life items
Results of the initial and final CPT and LPT before launch
All final hardware and software test data
Critical Parameters Trending Data
Technical Memos affecting design choices shall be kept on file with GSFC access
Engineering test Log Books
Top Level Instrument Traveler
List of any open items with reasons for items being open
Waivers/Deviations

Master Documents may be kept at NIVR with GSFC access to the data.

9.0 CONFIGURATION MANAGEMENT

9.1 Waiver/Deviation Requests

Waiver/Deviation Requests (Reference DRL 510) shall be submitted to the GSFC Chemistry Project Office for approval. Waiver/Deviation Requests shall be sequentially numbered. These requests shall include any impact that would result from NASA disapproval.

When a specific safety requirement can not be met, NIVR shall note the Waiver/Deviation form by the addition of the word "SAFETY".. In addition, the proposed method of controlling the additional risk and the residual risk after application of any additional controls shall be specified. (See paragraph 4.2.2)

9.2 Configuration Change Requests

Each Configuration Change Request (CCR) shall be sequentially numbered and classified as either Class I (major) or Class II (minor) (Reference DRL 512). CCR's shall be documented on NIVR's internal form. Only Class I changes affecting the spacecraft interface shall be provided to the project for approval and authorization to proceed. Class II changes shall be kept at NIVR's facility for information. The CCR shall contain sufficient technical, contractual, and cost impact summaries of impacted items to enable the project to evaluate the impact of the change.

Attachment A

Code 301 Design Review Guidelines

TECHNICAL DESIGN REVIEW GUIDELINES

Design reviews are essential to good engineering practice. Several decades of high reliability aerospace design have shown the most important contributors to reliability are:

- Application of effective design principles with appropriate peer reviews and periodic systems design reviews.
- Control and screening of parts and processes.
- Thorough inspection and end-to-end testing or "test it as you fly it."

These have been a part of the GSFC process for a considerable time. However, design review practices have varied considerable among the GSFC missions. It is the purpose of this document to establish guidelines for design reviews held by the Systems Review Office (SRO), Code 301.

Reviews held by the Systems Review Office are independent reviews and are not to be equated with reviews held by a Project, another Directorate or peer reviews.

GUIDELINES FOR CONDUCTING GSFC CODE 301 TECHNICAL DESIGN REVIEWS (9/1997)

1. INTRODUCTION

This document establishes guidelines for design reviews conducted by the Systems Review Office. It describes the material to be covered, the documentation requirement and the process for closure of all design review Request for Action (RFA).

These guidelines should be considered by every GSFC project involving the delivery of hardware or software for orbital flight or ground systems. Non-deliverable ground support equipment should also be a part of the review process. Requests for exceptions to the design review requirements should be referred to the Chief, Systems Review Office (SRO) , Code 301 within the Office of Systems Safety and Mission Assurance (OSSMA) Directorate (Code 300).

2. REQUIREMENTS

All GSFC managed flight missions, flight spacecraft, flight instruments, shuttle attached payloads, flight support ground systems and unique support equipment are subject to the technical design review process. The primary objective of the Technical Design Review Program (TDRP) is to enhance the probability of success of GSFC missions by identifying potential or actual design problems associated with its design, qualification, and operations in a timely fashion to minimize cost and schedule impacts. The Chief of the Systems Review Office, OSSMA, in conjunction with the individual Project Manager, and/or Principal Investigators (PIs) will develop design review requirements to be documented in the project mission assurance requirements. The Chief of the Systems Review Office may waive the requirement for some of these reviews based primarily on considerations of system complexity, criticality, extent of technological design, previous flight history, mission objectives, and/or any mandated constraints. The reviews will be based upon an appropriate selection from the following system reviews:

- System Concept Review (SCR)
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- Mission Operations Review (MOR)
- Pre-Environmental Review (PER)
- Pre-Shipment Review (PSR)
- Flight Operations Review (FOR)
- Launch Readiness Review (LRR)

The TDRP for each spacecraft will generally consist of PDR, CDR, MOR, PER, PSR, FOR, AND LRR. Where applicable, the TDRP for identical follow-on spacecraft will generally consist of MOR, PER, PSR, FOR, AND LRR.

The TDRP for each instrument will generally consist of PDR, CDR, PER, and PSR. Where applicable, the TDRP for identical follow-on instruments will generally consist PER and PSR.

The GSFC policies and practices will not be imposed on instruments provided by other NASA Centers and/or the Jet Propulsion Laboratory (JPL) which are not in-line with mission success. The other NASA Centers and/or JPL will have the sole responsibility for the instrument's performance and longevity. GSFC will only insure system safety and that the system interfaces are such that an instrument failure will not adversely affect other elements of the spacecraft or GSE. The review program for instruments provided by the other NASA Centers and/or JPL that are in-line with mission success will be tailored as appropriate.

The TDRP for GSFC supplied shuttle small payloads such as GAS, Hitchhiker, and Spartan, will, as appropriate, consist of a PDR, CDR, PER, and PSR. This will be applicable to all new designs for the small payload carrier systems including structural support hardware, separation devices, canisters, ACS, C&DH, power, and thermal subsystems. The review of instruments, during these reviews, will be limited to safety and compatibility status. Instruments supplied by GSFC will receive an independent CDR and PER. No TDRP activity is required for contained GAS instruments. Upon the successful completion of the review program, small payload carrier systems will be considered certified for the number of flights defined by the design and qualification criteria. After the first flight, the SSMA will conduct an independent PSR prior to each subsequent flight. Re-certification will be required after the certified number of flights has been completed. When changes from the baseline certified design are proposed, the project will consult the SRO to determine the appropriate independent reviews necessary for re-certification.

The TDRP for flight equipment supplied by GSFC to another NASA Center's spacecraft, DOD spacecraft, or foreign spacecraft will be treated as if they were to fly on a Goddard spacecraft and will be subject to the requisite review program.. In the event the other party involved has an independent review program essentially equivalent to the GSFC program, their program may be substituted after supplying acceptable justification to the Chief of the Systems Review Office, SSMA. In return, GSFC will make a reasonable attempt to comply with the review requirements of the other organization.

The TDRP for flight equipment supplied to GSFC by another organization (non-NASA or JPL) will be treated as if it were GSFC equipment to fly on a GSFC spacecraft and will be subject to the same requisite GSFC review program. In the event that the other organization has an independent review program equivalent to the GSFC program, their program may be substituted after supplying acceptable justification to the Chief of the Systems Review Office, OSSMA. Tailoring of the review program is permitted by mutual agreement to the intent of the GSFC TDRP. Tailoring is subject to approval of the Chief of the systems Review Office, OSSMA.

The TDRP for new, project unique ground systems will consist of PDR and CDR. The ground system is also a major subject of the mission-oriented reviews SCR, MOR, FOR, and LRR. An appropriate Directorate review team will normally review generic facilities newly developed or significantly modified by the Mission Operations and Data System Directorate (MO&DSD). Readiness of the "new" system for mission support will be reviewed through the mission LRR conducted by the SRO the first time the generic system is to be used in a prime support mode.

The Sounding Rocket and Balloon flight programs are exempted from the Systems Review Office review program.

3. RESPONSIBILITIES

The Chief, Systems Review Office will assign a chairperson from the Systems Review Office, for each design review. The chairperson or SRO Manager, in concert with the Project Manager and/or PI, and other Directorates, appoints key technical experts as review team members. If the required discipline expertise is not available within the center, membership from other NASA centers will be considered. Review team members are to be approved by the Chief, Systems Review Office. The review team members are independent and generally not part of or directly associated with the design being reviewed. Review team members are expected to attend the entire design review. Once a review team has been established for a given project, every attempt will be made to maintain the continuity of the team throughout the life of the project. Additional team members may be added and others deleted as appropriate for each of the reviews, however a core review team should be maintained.

It is the chairperson's obligation to control and maintain the pace of the design review and to keep it on schedule. All participants are to be given their say and no pertinent questions are to be excluded at the review. If additional time is needed, it is the chairperson's responsibility to arrange a splinter meeting to assure that all questions and the necessary discussion takes place in an appropriate time frame. The solution of identified problems is not attempted at the review, but is assigned as a Request for Action (RFA). It is the responsibility of all review team members to submit any Requests for Action to the review chairperson in writing in the designated format.

At the end of the review, the chairperson will summarize his concerns in a short presentation to the Project Team and will either schedule a caucus of the review team members and key project management representatives or conduct an immediate open forum caucus to discuss and consolidate the actions to be submitted to the project, i.e. the SRO Manager should consider the appropriateness of adding time to the agenda, up to a half a day, to consolidate and review with the project all the RFAs submitted. The chairperson should also ensure that all RFAs are applicable to the review and do not constitute peer review type information.

It is the responsibility of the chairperson or SRO Manager to prepare and publish a report of the review with all the Requests for Actions within 30 days of a design review. In order to avoid any miscommunication or misunderstanding, the SRO Manager should consider requesting that the project review and comment on the RFAs as well as the report prior to its formal transmittal. Obviously, the report represents the results of an independent review team and, as such, the final version is at the discretion of the SRO Manager.

It is expected that all reviews will be presented in a professional manner. All design reviews require a presentation package. The review presentation package is to be prepared containing the subject to be reviewed in sufficient detail for a technical person to reasonably understand the design and make a proper evaluation as to its adequacy. The presentation package, ideally, should be given to each member of the review team a minimum of 5 working days before the review is scheduled to take place. The design review presentation is to be made with supporting view-graphs, which may be a summation of the material contained in the presentation package. All of the major points contained in the presentation package are to be presented at the review. It is recommended that all reviews be held at the location of the developer/manufacturer of the item being reviewed.

The Project Manager, or applicable person, is responsible for seeing that the design reviews are held in accordance with the TDRP that is negotiated at the beginning of the project or mission with the review chairperson or SRO Manager and approved by the Chief, Systems Review Office. The Project Manager or his designee is responsible for the review presentation and the preparation of the review presentation material. The agenda for the design review is to be developed by the Project Manager along with the review chairperson to assure the content to be presented covers the intended scope of the design review. The agenda is to be available with the presentation package. Timely notification is to be given to the review chairperson when a review is to be scheduled. The Project Manager also assures that his presenters are prepared and that the review packages are issued on time. Finally, the Project Manager is responsible for seeing that responses are issued to the review team Requests for Action within 30 working days after receipt of the review team report. For those responses that will require longer than the 30 days, a schedule is to be worked with the review chairperson for an acceptable response date. It is the design review chairperson's responsibility to assure that all Request for Actions are closed out to the satisfaction of the review team.

4. REVIEWS

4.1 SYSTEM CONCEPT REVIEW (SCR)

The SCR is held to assure that the objectives and requirements of the item being designed are understood and that the proposed approach will meet these requirements. The emphasis should be on the requirements, how they flow down, the proposed design concept and the definition of the major system interfaces. Detailed interfaces are to be presented at later reviews.

The SCR should occur near the end of the conceptual design or study phase on larger programs. For smaller programs, the SCR may be combined with the next level of review. The SCR should occur early enough so that the concept can be modified without a major impact on the program. The review should present the major design alternatives considered, the relative risk for each and the reasons for the approach chosen by the design team.

The SCR should address the following items:

- Mission/Object Design Objective
- Science Requirements
- Constraints
- Technical / Performance Requirements
- Organizational Interfaces
- Technical Interface
- System Drivers
- Safety Considerations
- Risk Area
- Proposed Design Approach
    - System Design
    - Mechanical
    - Electrical
    - Thermal
    - Software
- Ground Support Equipment (GSE)
- Operations
- Planned Test Program

The output of the SCR is a baseline design subject to the closure of any action items resulting from the review. This then becomes the baseline for the detailed design.

4.2 PRELIMINARY DESIGN REVIEW (PDR)

The PDR is the first major review of the detailed design and is normally held prior to the preparation of formal design drawings. A PDR is held when the design is advanced sufficiently to begin some bread board testing and /or the fabrication of design models. Detail designs are not expected at this time, but system engineering, resource allocations and design analyses are required to demonstrate compliance with requirements. A presentation of the design and interfaces by means of block diagrams, signal flow diagrams, schematics, logic diagrams, error budgets, link margins, first interface circuits, packaging plans, configuration and layout sketches, analyses, modeling and any early results are required. Estimates of weight, power, volume and the basis for the estimates of these parameters are required. Supporting data and analyses for mechanical, power, thermal, and electronic design: load, stress, margins, reliability assessments, should be shown. Software requirements, design, structure, logic flow diagrams, Central Processing Unit (CPU) loading, design language and development systems need to be specified. Parts selection, de-rating criteria, and radiation hardness, is an important part of the PDR. The identification of single point failure modes needs to be assessed as well as critical design areas which may be life limiting.

A PDR should cover the following items:

- Science/Technical Objectives, Requirements, General Specification
- Closure of Actions from Previous Review/Changes since the last review
- Performance Requirements
- Error budget determination
- Weight, Power, Data rate, Commands, EMI/EMC
- Interface Requirements
- Mechanical/structural design, analyses, and life tests
- Electrical, thermal, optical/radiometric design and analyses
- Software requirements and design
- Ground Support Equipment design
- System Performance budgets
- Design verification, test flow and calibration/test plans
- Mission and ground system operations
- Launch Vehicle interfaces and drivers
- Parts selection, qualification, and Failure Mode and Effects Analysis (FMEA) plans
- Contamination requirements and control plan
- Quality Control, Reliability and redundancy
- Materials and Processes
- Acronyms and abbreviations
- Safety hazards identified for flight, range, ground hardware and operations
- Orbital Debris Assessment

The completion of the PDR and the closure of any actions generated by the review become the basis for the start of the detailed drafting and design effort and the purchase of parts, materials and equipment needed.

4.3 CRITICAL DESIGN REVIEW (CDR)

The CDR is held near the completion of an engineering model, if applicable, or the end of the breadboard development stage. This should be prior to any design freeze and before any significant fabrication activity begins. The CDR presents a final detailed design using substantially completed drawings, analyses and breadboard/engineering model evaluation testing to show that the design will meet the final performance and interface specifications and the required design objectives. The CDR should represent a complete and comprehensive presentation of the entire design. It should present the final design and interfaces by means of block diagrams, power flow diagrams, signal flow diagrams, interface circuits, layout drawings, software logic flow and timing diagrams, design language, modeling results, breadboard and engineering model test results and changes required to the design presented at the PDR. Final estimates of weight, power, and volume are to be presented. Final calculations for mechanical loads, stress, torque margins, thermal performance, radiation design and expected lifetime are to be presented. Final software requirements and updated system performance estimates should also be presented. Parts selection, de-rating criteria and screening results, calculated reliability and the results of a FMEA are to be presented.

The CDR should include all of the items specified for a PDR, updated to the final present stage of development process, plus the following additional items:

- Evolution and Heritage of the Final Design
- Combined optical, thermal, and mechanical budgets or total system performance
- Closure of Actions from the Previous Review
- Interface Control Documents
- Final implementation plans including: engineering models, prototypes, flight units, and spares
- Engineering Model/Breadboard Test Results and Design Margins
- Completed design analyses
- Software detailed design and test plans
- Qualification/Environmental Test Plans and Test Flow
- Launch Vehicle Interfaces
- Ground Operations
- Progress/status and control methods for all safety hazards identified at, but not limited to, the PDR
- Reliability analyses results: FMEA, Worst Case Analysis, Fracture Control
- Plans for shipping containers, environmental control and mode of transportation
- Problem Areas/Open Items
- Schedules

Completion of the CDR and resolution of all the action items generated by it constitutes the baseline design for the item to be built. Following the CDR, drawings are released and formal configuration control begins.

4.4 MISSION OPERATIONS REVIEW (MOR)

The MOR is the first of the two reviews, which concentrate on the ground system and flight operations preparations. All mission-oriented operations will be addressed including science, spacecraft and ground systems operations. The overall design and status of the ground system is reviewed to assure that the requirements for science and spacecraft operations support and for data processing and analysis support are understood and that the proposed approach will meet the requirements. The operational interfaces between the ground system and flight system will be reviewed with respect to proper system engineering of operational trade-off, signal link margins, constraints, and modes of operation including safe modes. Mission integration of pre-launch test planning including all planned tests between the flight segment and the ground system will be reviewed. The relationship between planned ground system software releases/capabilities and planned tests with the flight segment will be included. The plans and status for flight operations team and science operations preparations will be presented. The mission operations review should occur prior to significant integration and test of the flight system and ground system and should address the following items:

- Objectives
- Overall schedule and status including: documentation (i.e. spacecraft operations concept, ground system requirements, flight operations and contingency plans and Interface Control Documents)
- Closure of previous reviews (e.g. Project-unique ground system reviews)
- Mission, science, spacecraft, flight software, and ground system overviews
- Flight software maintenance approach
- Flight operations team build up and training plans
- Pre-launch test plans including: RF and POCC compatibility tests, data flow and end-to-end tests, simulations and exercises, launch site and pad tests
- Launch and early orbit overview including deployment activities and coverage
- In-orbit checkout overview
- Project database and procedure development
- Spacecraft and instrument operations constraints
- Spacecraft subsystem level activities
- Mission planning and scheduling
- On-board data memory management
- Real-time operations including: health and safety monitoring, safe mode operation
- Trend analysis plans including reports and archive
- Science operations planning, data processing and analysis
- Ground system requirements and development status
- Mission readiness testing
- Preliminary list of all launch critical facilities and function
- Issues and concerns

4.5 PRE-ENVIRONMENTAL REVIEW (PER)

The PER is required prior to the start of formal environmental testing. The purpose of the PER is to evaluate the planned test/calibration program and test flow to assure that it meets the program needs and to assure that a proper baseline of performance of the item to be tested has been established, and the item is ready to begin a qualification test program to demonstrate end-to-end or system performance. All performance liens, waivers, action items, malfunction reports and open items should be closed or disposition. Could-Not-Duplicates (CNDs) should not be closed and their discussion or risk assessment should include what fault tree was done, possible causes, testing/on-orbit impacts, as well as "can we see it" in the follow-on test phases. The test verification matrix, including measurement tolerances, stimuli, contamination control, and facility readiness are to be presented. The results of sub-level testing, results since the last review, and results from the Comprehensive Performance Test (CPT) should be discussed along with the final results of any life tests. Failure free operating time on the item to be tested should be presented. The following gives a list items, which should be presented at the PER:

- Changes since the Critical Design Review
- Program status and general test readiness
- Test Plans and procedures addressing:
- Test objectives/conditions/levels/configuration
- Test facilities and certification
- Test fixtures and support equipment
- Instrumentation
- Success/abort criteria
- Progress/status of safety data submissions, procedures and verification
- Test flow including: calibration, when CPTs will be performed and number of thermo-vac cycles
- Schedule
- Documentation Status
- Functional and environmental test history of the hardware
- Proof of readiness of flight software to support environmental tests
- Product Assurance and Safety
- Previous anomalies, deviations, waivers and their resolution
- Identification of residual risk items
- Open items and plans for close-out
- Final Calibration

Following a successfully completed PER and the closeout of any remaining items, the hardware is ready to begin its environmental qualification or acceptance test program.

4.6 PRE-SHIPMENT REVIEW (PSR)

The PSR occurs prior to the shipment of the item to its destination. The purpose of the PSR is to assure the design of the item has been validated through the environmental qualification and/or acceptance test program, that all deviations, waivers and open items have been satisfactorily disposition and that the item, along with all the required documentation, operating procedures, etc., is ready for shipment. The results of system testing, alignment, calibration and end item performance are to be demonstrated and documented. The solutions to all problems encountered during the environmental test and validation program and the solution rationale are to be presented. Items that should also be considered as part of the presentation are:

- Any rework/replacement of hardware, regression testing, or test plan changes should be highlighted during the test flow discussions
- Compliance with the test verification matrix
- Measured test margins versus design estimates
- Demonstrate qualification/acceptance temperature margins
- Any data that has been trended to identify compliance with specification should be presented, especially it there has been a change or drift to the trend.
- Total failure-free operating time of the item
- Could-not-duplicate failures should be presented along with assessment of the problem and the residual risk that may be inherent in the item
- Project assessment of any residual risk
- Verification that limited life items are within mission requirements
- Update from CDR on shipping containers, monitoring/transportation/control plans
- Ground support equipment status
- Post shipment plans
- Launch preparation plan
- Approval of safety status for flight, range, ground hardware and operations

Satisfactory completion of the pre-shipment and the closeout of any actions from the review indicate the item is ready for shipment.

4.7 FLIGHT OPERATIONS REVIEW (FOR)

The FOR is held near the completion of pre-launch testing between the flight segment and the ground system. The plans for final end-to-end testing and simulations will be reviewed. The results of previous testing will be included (i.e. discrepancy summary, network compatibility assessment, training status, etc.). The final launch, orbital operations, and checkout plans will be presented.

The FOR should include all of the items specified for a MOR, updated to the present stage of progress, plus the following additional items:

- Closure of actions from the MOR
- New requirements and changes in plans
- Test result summaries including the Project's assessment of the criticality of open problems
- Work remaining including tests, simulations, and closure of problems
- Personnel location for L&EO and IOC including Project office, operations, and spacecraft subsystem expert personnel.
- Contingency procedures, development and verification/validation status

4.8 LAUNCH READINESS REVIEW (LRR)

The GSFC LRR assesses the overall readiness of the mission and is normally held three days prior to a scheduled launch. It is a review of the total system to support the flight objectives of the mission. It is a review of the flight hardware and software, the launch vehicle, all the ground support systems, and the launch and orbital operations for their readiness to support the launch.. The review is to cover all the activity since the Pre-Shipment Review and the Flight Operations Readiness review, the closure of any actions from those reviews and a summation of all the testing and launch operations planning and rehearsals to the present. Any open items and residual risks are to be presented at this time. Closure of this review and any actions generated from the review indicate the mission is ready for launch.

Attachment B

Performance Assurance Requirements for EOS Common Spacecraft Document Number 420-05-04, Section 3

This attachment is excerpted from the Performance Assurance Requirements for the EOS Common Spacecraft, Document Number GSFC 420-05-04, Section 3. **It must be reviewed to obtain the latest revision** applicable to the EOS Chemistry Mission. It is available upon request from the EOS Library.

3. PERFORMANCE VERIFICATION REQUIREMENTS

3.1 GENERAL REQUIREMENTS

A Performance Verification Program shall be conducted to ensure that the EOS Spacecraft Bus and Spacecraft meet the specified mission requirements. The program consists of a series of functional demonstrations, analytical investigations, physical property measurements, and environmental tests that simulate the environments encountered during handling and transportation, prelaunch, launch, ascent, and in-orbit operations. All protoflight hardware shall undergo qualification to demonstrate compliance with the requirements of this Section. All other flight hardware (as defined in Appendix B, "Hardware") shall undergo acceptance verification in accordance with the requirements of this Section unless specific modifications are permitted in a subparagraph entitled "Acceptance Requirements." The Performance Verification Program begins with functional testing of assemblies, continues through the functional and environmental testing, supported by appropriate analysis, at the component and subsystem levels of assembly. Methods for implementing the requirements of this Section are contained in the expendable launch vehicle (ELV) payload requirements of the General Environmental Verification Specification for Space Transportation System (STS) and ELV Payloads, Subsystems and Components (GEVS-SE) (see Appendix A herein).

The ELV payload requirements of GEVS-SE and the mission requirements establish the general environmental test requirements for the EOS missions. Test levels shall encompass predictions based on launch vehicle information available in the EOS Spacecraft to ELV interface control document. Test requirements shall be updated if necessary based on Spacecraft structural analyses and modal survey.

Figures 3-1a, 3-1b and 3-1c, respectively, provide general graphic overviews of the verification flows for EOS spacecraft, Spacecraft modular subsystems, and Spacecraft components as called for in this Section of the PAR. These are provided to support the narrative description of the flow.

3.1.1 System Safety Considerations – Certain additional activities (not identified in this Section) that are needed to satisfy the safety requirements of section 4 may best be accomplished during the Performance Verification Program. It is therefore recommended that, in order to achieve cost and scheduling benefits, the Performance and Safety Verification Programs is closely coordinated.

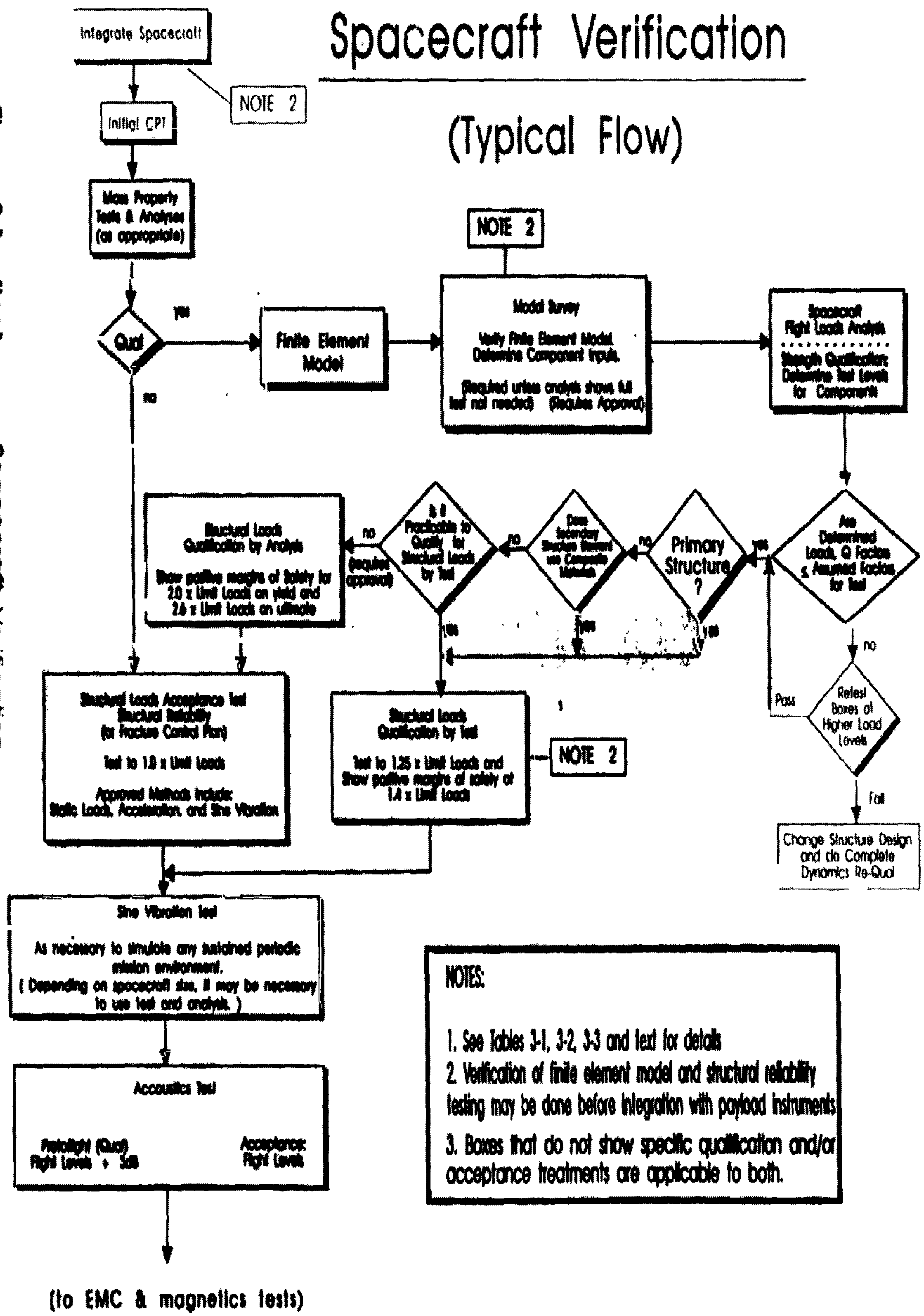

Figure 3-1a (top) - Spacecraft Verification

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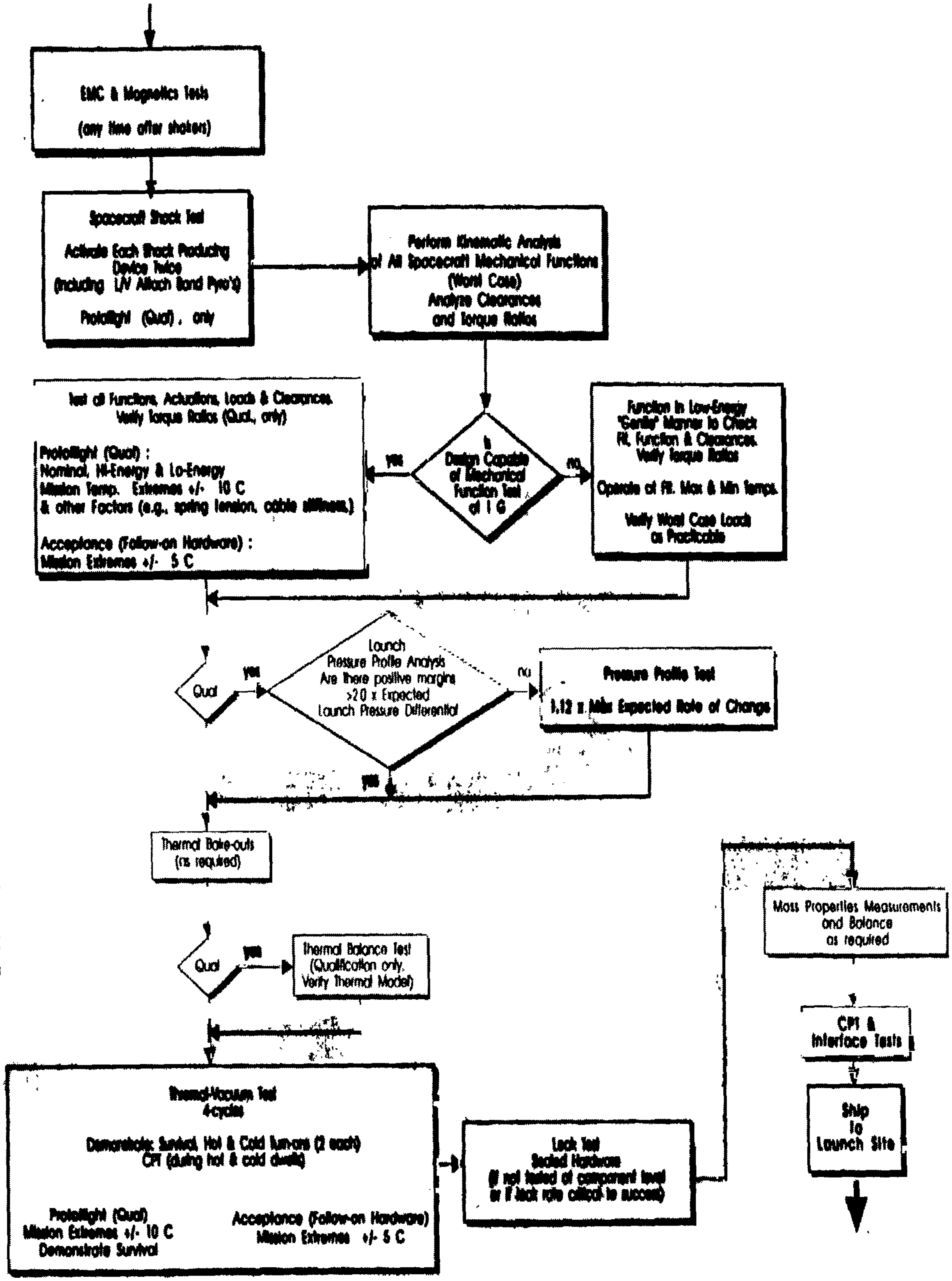

Figure 3-1a (bottom) Spacecraft Verification (Cont'd)

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Modular Subsystem Verification

(Typical Flow)

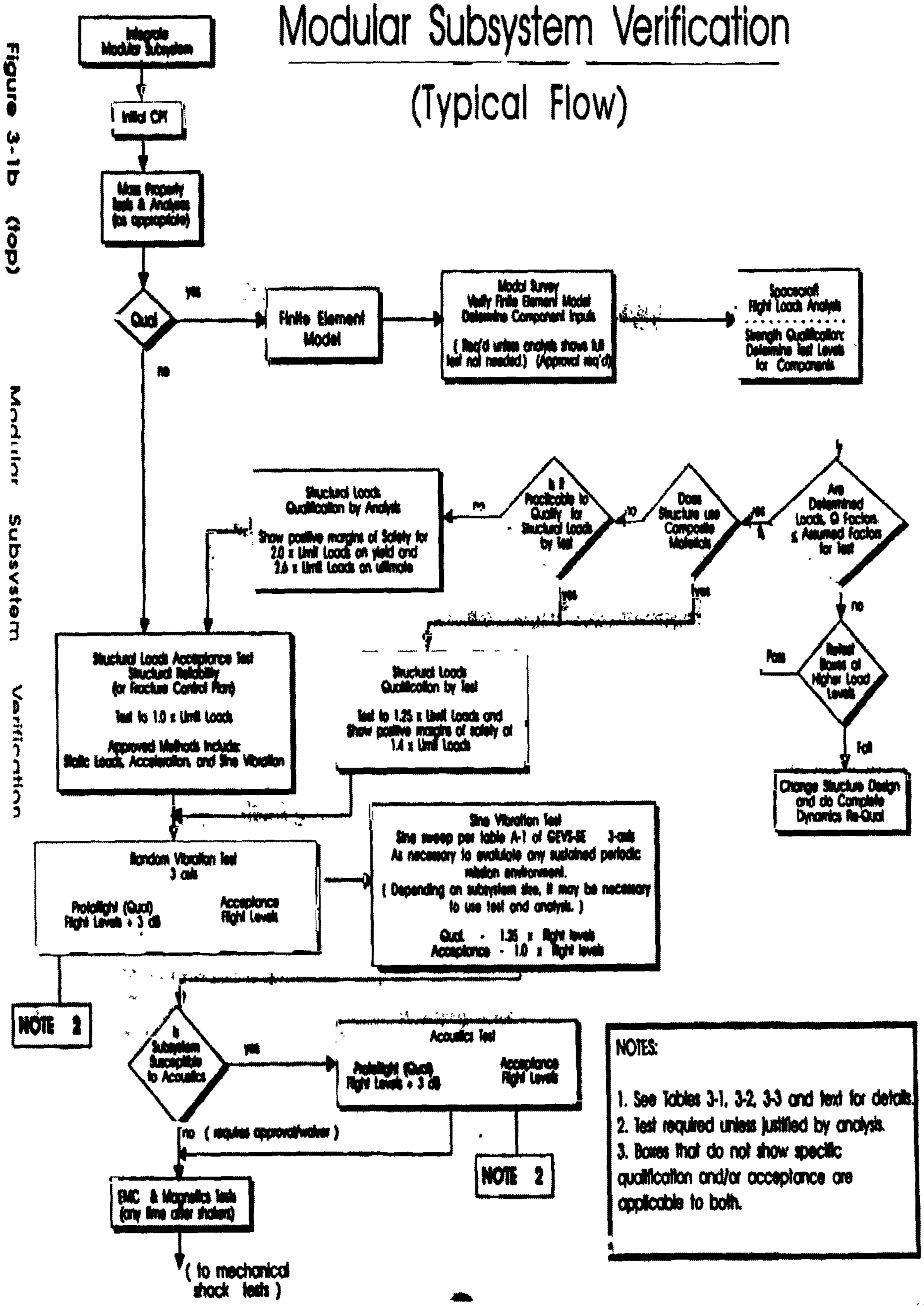

Figure 3-1b (top) Modular Subsystem Verification

20 January 3, 1994

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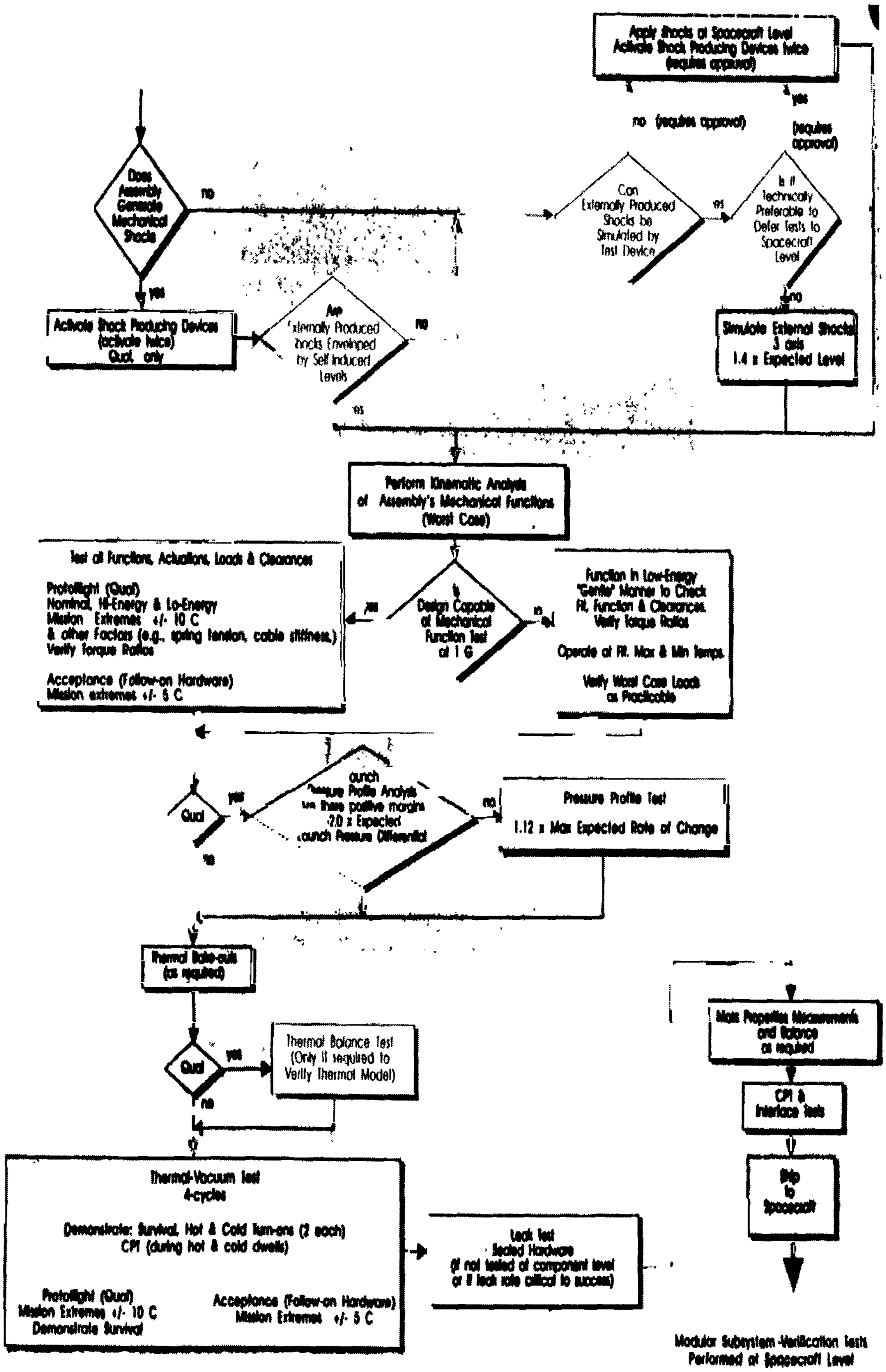

Figure 3-1b (bottom) - Modular Subsystem Verification (cont'd)

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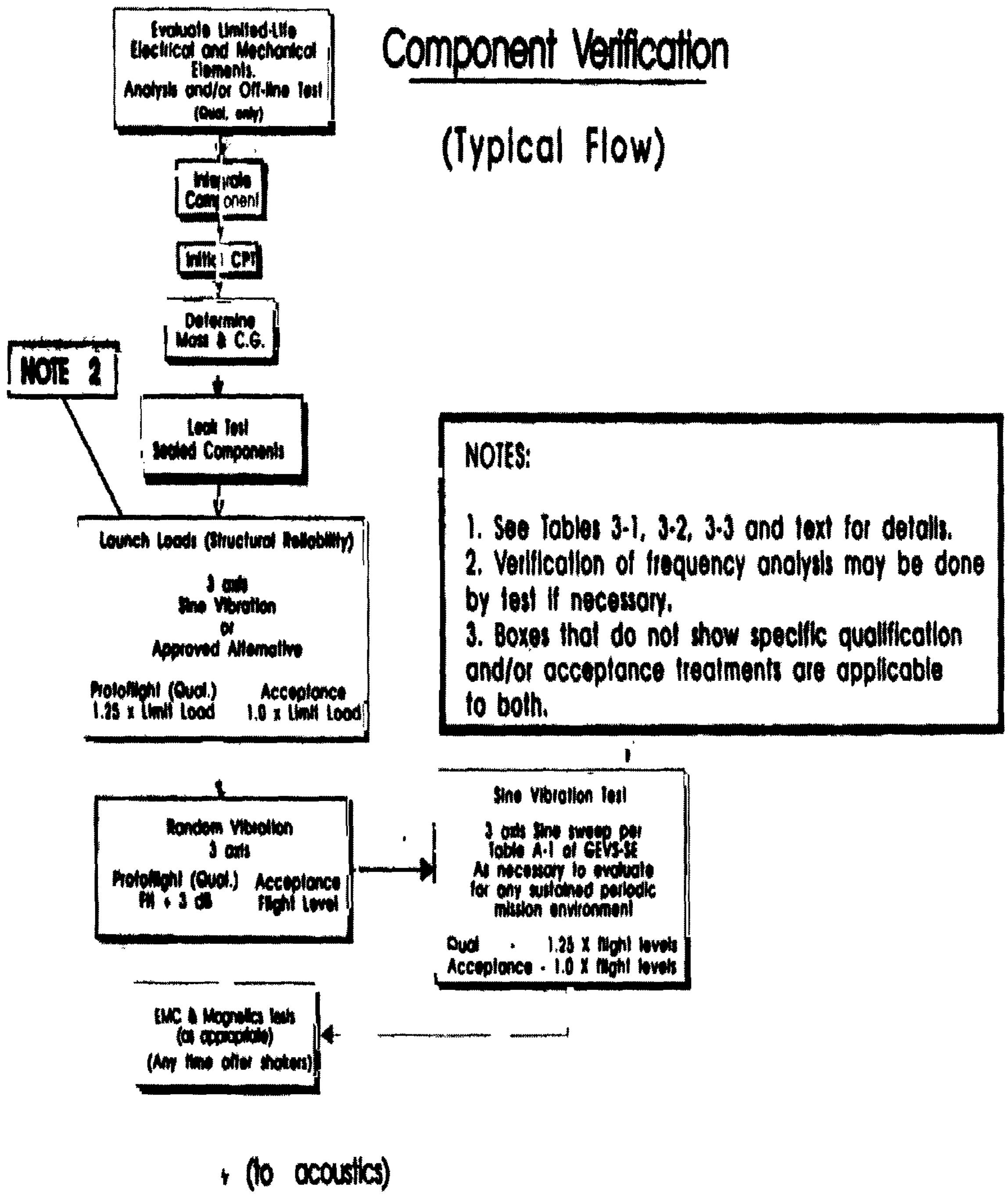

Figure 3-1c (top) - Component Verification

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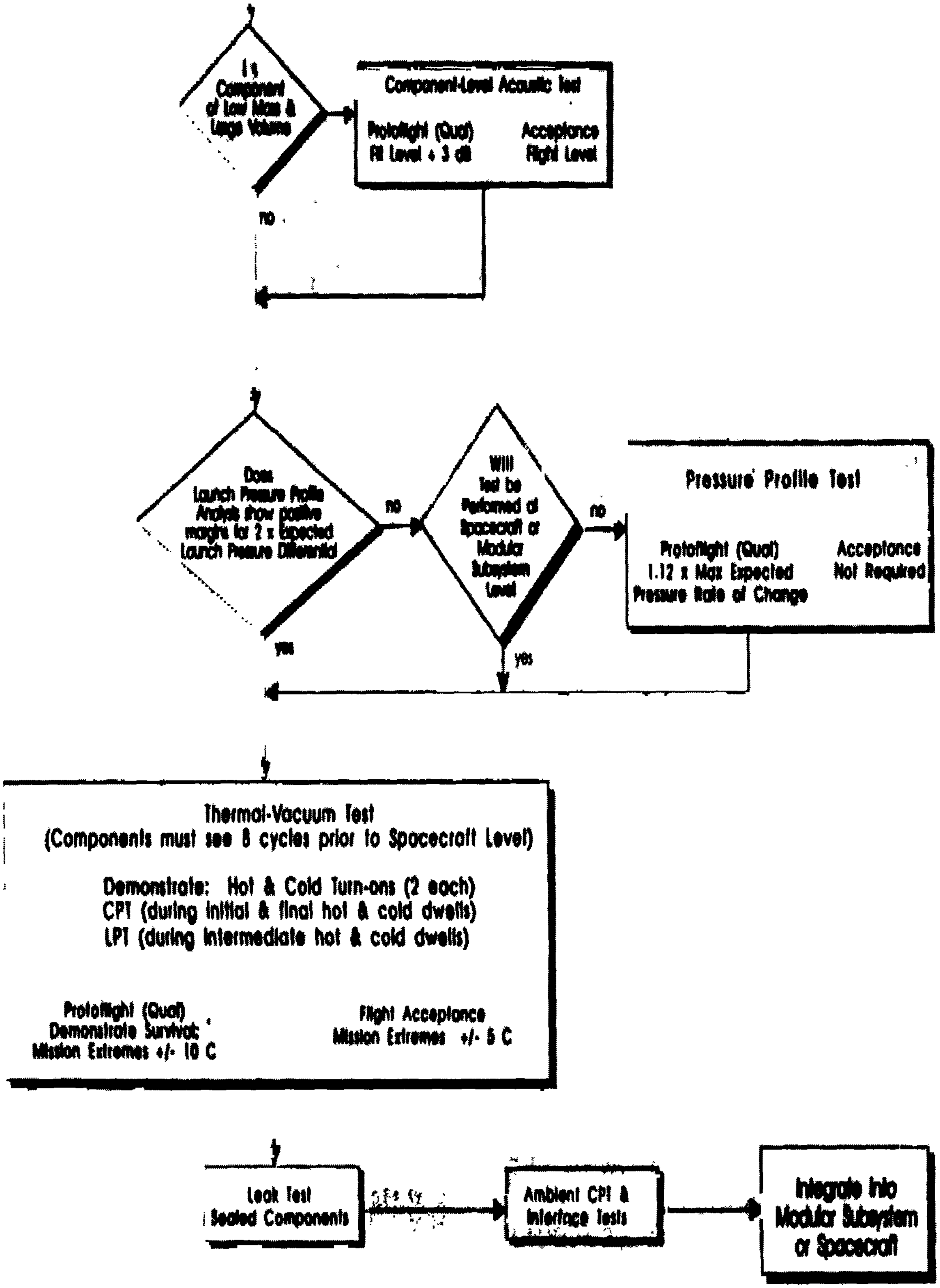

Figure 3-1c (bottom) Component Verification (continued)

January 3, 1994

3.2 DOCUMENTATION REQUIREMENTS

The approach for accomplishing the Performance Verification Program shall be described in the Verification Plan (see section 3.2.1 herein). This shall include a description of the management approach as well as the following plans, specifications, procedures, and reports, which are required to define the technical aspects of the Performance Verification Program.

- Verification Plan - A Verification Plan shall be prepared and maintained up-to-date that defines the analyses that collectively demonstrate that the hardware and specific tests and software/firmware complies with sections 3.2 through 3.7 and Section 10 of this document.

The Verification Plan shall provide the overall approach to accomplishing the Verification Program. For each test, it shall include the level of assembly, configuration of the item, objectives, facilities, instrumentation, safety considerations, contamination control, test phases and profiles, necessary functional operations, personnel responsibilities, and requirements for procedures and reports. It shall also define a rationale for retest determination that does not invalidate previous verification activities. When appropriate, the interaction of the test and analysis activity shall be described. For each analysis activity, the plan shall include objectives, a description of the mathematical model, assumptions on which the models will be based, required output, criteria for assessing the acceptability of the results, the interaction with related test activity, if any, and requirements for reports.

As an adjunct to the Verification Plan, a verification matrix shall be prepared that summarizes all tests and analyses that will be performed on each component, each subsystem, the Spacecraft Bus, and the Spacecraft, as a whole. The contractor shall update the test matrix as the contractor/subcontractor tests are actually accomplished throughout the program and present it at the pertinent GSFC reviews called for in section 2. The Verification Plan shall be delivered to NASA and updated in accordance with the CDRL.

CH-01

3.2.2 Verification Specification - A Verification Specification shall be prepared that stipulates the specific environmental parameters associated with each of the tests and analyses required by the Verification Plan. This specification may be combined with the Verification Plan. In defining quantitative environmental parameters under which the hardware and software/firmware elements must meet their performance requirements, the Verification Specification shall consider things such as Spacecraft peculiarities and interactions with the EOS launch vehicle.

The Verification Specification shall be delivered to NASA and updated in accordance with the CDRL. CH-01

3.2.3 Verification Procedures - For each functional and environmental test activity conducted at the component, subsystem, Spacecraft Bus, and Spacecraft level, verification procedures shall be prepared that describe the configuration of the test article and how that particular test activity contained in the Verification Specification and Verification Plan will be implemented.

CH-01

The procedures shall describe details such as instrumentation monitoring, facility control sequences, test article functions, test parameters, quality control checkpoints, pass/fail criteria, data collection, and reporting requirements. The procedures shall also have attached test predictions and shall address safety and contamination control provisions and measures to protect the hardware (e.g. connector savers). Procedures for calibrations and performance tests shall provide for real-time display of data in easily recognized engineering terms to the maximum extent practicable. Verification Procedures shall be made available to NASA upon request.

3.2.4 Control of Unscheduled Activities During Verification - A documented procedure shall be established for controlling, documenting, and approving all activities not part of an approved verification procedure or flight instrument calibration procedure. The contractor shall be alert to the hazard potential of last minute changes and shall institute controls at appropriate management levels to prevent accident or injury or hardware damage. Such control shall include appropriate real-time decision making mechanisms to expedite continuation, or suspension, of testing after a malfunction, with documented rationale. The control procedure shall be documented in accordance with the CDRL, and it shall be referenced in the Verification Plan (see section 3.2.1) and in each verification procedure.

In the event of failure of a flight instrument at the Spacecraft contractor's facility, the contractor shall stop the test and contact the Contracting Officer's Technical Representative (COTR) or the COTR's designee before proceeding. Normally, the complete test shall be rerun, starting at the beginning of the test in which the failure occurred, unless the retest is shortened upon direction of NASA. The exact nature of retest shall be determined by the COTR. CH-01

3.2.5 Verification Reports - After completion of each component, subsystem, Spacecraft Bus, and Spacecraft verification activity or flight instrument calibration, a report shall be submitted in accordance with the CDRL. For each test activity, the report shall contain, as a minimum, the information described in the sample test report (see Figures 3-2a and 3-2b). For each analysis activity, the report shall describe the degree to which the objectives were accomplished, how well the mathematical model was validated by the test data, and other significant results. Detailed test and analysis data supporting the verification reports shall be retained by the contractor; this data, as well as the as-run verification procedures, shall be available for review at the contractor's facility upon request.

CH-01

3.3. ELECTRICAL FUNCTION TEST REQUIREMENTS

3.3.1 Electrical Interface Tests - Before the integration of an assembly, component, or subsystem into the next higher hardware assembly, electrical interface tests shall be performed to verify that all interface signals are within acceptable limits of applicable performance specifications.

During integration, the electrical harnessing shall be tested to verify proper routing of electrical signals. This verification shall include isolation tests on signal ground, power ground, and signal and power lines using breakout boxes and/or tees. Harnesses shall also be tested as required in NHB 5300.4(3G) (see also section 8.10.3 herein). All such testing, as well as the accompanying integration activities, shall be performed in an area that conforms to the cleanliness criteria developed in response to section 9.

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Page ____ of ____

VERIFICATION TEST REPORT

PROJECT ______________________________

TEST ITEM ______________________________

MANUFACTURER ______________________________

SERIAL NUMBER ______________________________

LEVEL OF ASSEMBLY: ☐ COMPONENT ☐ SUBSYSTEM ☐ PAYLOAD

TYPE HARDWARE: ☐ PROTOTYPE ☐ PROTOFLIGHT ☐ FLIGHT ☐ SPARE

TYPE TEST:

☐ STRUCTURAL LOADS
☐ VIBRATION
☐ ACOUSTICS
☐ MECHANICAL SHOCK
☐ MECHANICAL FUNCTION
☐ MODAL SURVEY
☐ PRESSURE PROFILE
☐ MASS PROPERTIES
☐ ELECTROMAGNETIC COMPATIBILITY
☐ MAGNETIC PROPERTIES
☐ THERMAL - VACUUM
☐ THERMAL BALANCE
☐ THERMAL CYCLING
☐ TEMPERATURE - HUMIDITY
☐ LEAKAGE
☐ COMPREHENSIVE PERFORMANCE

☐ OTHER (explain) ______________________________

VERIFICATION PROCEDURE NO ____________ REV. ____________ DATE ____________

☐ INITIAL TEST

☐ RETEST (☐ PARTIAL OR ☐ FULL; STARTING DATE OF INITIAL TEST ____________)

APPLICABLE VERIFICATION PLAN: ______________________________

FACILITY DESCRIPTION: ______________________________

LOCATION: ______________________________

TEST LOG REFERENCE: ______________________________

COMMENTS.

SIGNATURE:

QUALITY ASSURANCE REPRESENTATIVE: ____________________ DATE ____________

COGNIZANT ENGINEER FOR TEST ITEM: ____________________ DATE ____________

Figure 3-2a Verification Test Report

27 Draft, May 5, 1993

3.3.2 Performance Tests

3.3.2.1 Comprehensive Performance Tests (CPT's). A CPT shall be conducted on each hardware element upon completion of integration of all assemblies. When environmental testing is performed at a given level of assembly, additional CPT's shall be conducted during the hot and cold extremes of the temperature or thermal-vacuum test and at the conclusion of the environmental test sequence, as well as at other times prescribed in the Verification Specification.

The CPT shall be a detailed demonstration that the hardware meets its performance requirements within allowable tolerances. The test shall demonstrate operation of all redundant circuitry. It shall also demonstrate satisfactory performance in all operational modes within practical limits of cost, schedule, and environmental simulation capabilities. The initial CPT shall serve as a baseline against which the results of all later CPT's are compared.

At the Spacecraft Bus and Spacecraft levels, the CPT shall demonstrate that, with the application of known stimuli, the system will produce the expected responses. At lower levels of assembly, the test shall demonstrate that, when provided with appropriate stimuli, internal performance is satisfactory and outputs are within acceptable limits.

3.3.2.2 Limited Performance Tests. Limited performance tests shall be conducted before, during, and after environmental tests, as appropriate, in order to demonstrate that functional capability has not been degraded by the environmental tests. Limited performance tests are also used in cases where a CPT is not warranted or not practicable. Specific times at which limited performance tests will be conducted shall be prescribed in the Verification Specification. Limited performance tests shall demonstrate that the performance of selected functions is within acceptable limits.

3.3.2.3 Limited Life Electrical Elements.. A life test program shall be considered for electrical elements that have limited lifetimes. The Verification Plan and Verification Specification shall address the life test program, identifying the electrical elements that require such testing, describing the test hardware that will be used, and the test methods that will be employed. Limited life electrical items shall be included in the limited life list as required in section 7 of this document.. (See also section 3.4.7.3 on life testing of mechanical elements.)

3.3.2.4 Trouble Free Performance. At the conclusion of the performance verification program, the Spacecraft shall have demonstrated minimum reliability acceptability by trouble-free performance for at least the last 100 hours of (combined) testing prior to launch. Trouble-free operation during the thermal vacuum test exposure and during testing of the integrated Spacecraft may be included as part of the demonstration. Hardware or software changes during or after the verification program shall invalidate previous demonstration.

3.4 STRUCTURAL AND MECHANICAL REQUIREMENTS

3.4.1 General Requirements - The contractor shall demonstrate compliance with structural and mechanical requirements with a series of interdependent test and analysis activities. The baseline requirements are stated in the ELV payload requirements of GEVS-SE. The demonstrations shall verify design and specified factors of safety, ensure interface compatibility among the elements of the Spacecraft and with the launch vehicle, acceptable workmanship, and compliance with associated systems safety requirements.

3.4.2 Requirements Summary - Table 3-1 specifies the structural and mechanical verification activities. When planning the tests and analyses, the contractor shall consider all expected environments including those of structural loads, vibroacoustics, mechanical shock, and pressure profiles. Mass properties and mechanical functioning shall also be verified.

3.4.3 Structural Loads -

3.4.3.1 Verification for Design Qualification.. Verification for the structural loads environment shall be accomplished by a combination of test and analysis. A modal survey shall be performed to verify that the analytic model of the EOS Spacecraft hardware adequately represents its dynamic characteristics. The test-verified model shall then be used to predict the maximum expected load for each potentially critical loading condition, including handling and transportation, and vibroacoustic effects during lift-off. The maximum loads resulting from the analysis define the limit loads.

For small, rigid spacecraft structures or modular components, an alternative to the above modal survey requirement may be allowed if approval of the Contracting Officer is obtained. This approach requires that an analysis be performed to ascertain the resonant frequencies of the spacecraft's or modular subsystem's fixed base modes. Where the analysis clearly shows the fundamental frequency to be above 100 Hz, verification by test is not required. For structures whose analysis indicates a resonant frequency below 100 Hz, a sine sweep shall be performed to determine the fundamental resonant frequency. Where this is found to be below 70 Hz, a modal survey shall be performed to verify that the analytic model of the hardware adequately represents its dynamic characteristics. Test verification for structures with fundamental fixed-base modes above 70 Hz may be limited to the frequency verification test (low level sine sweep). Spacecraft or modular subsystems with fundamental fixed-base modes above 100 Hz shall supply an analytical rigid mass representation.

The preferred method of verifying adequate strength is to apply a set of loads equal to 1.25 times the limit loads after which the hardware must be capable of meeting its performance criteria. In order to comply with the safety criteria, the strength verification test must be accompanied by a stress analysis that predicts that no ultimate failure will occur at loads equal to 1.40 times limit and that yielding will not occur at loads equal to 1.25 times limit. If the above analysis and proof testing to 1.25 times limit loads are successfully performed, additional verification is not required for qualification.

Table 3-1 Structural and Mechanical Verification Requirements

Requirement	Spacecraft	Modular Subsystem	Component (of Spacecraft Bus)
Structural Loadfs:			
Modal Survey or Frequency Verification	A-T	T_1	A/T_2
Load Tests:			
Design qual	A-T	A; T	A; T_1
Structural Rel.	A/T	A/T	A/T
Vibroacoustics:			
Acoustics	T	T_1	T_1
Random Vibration	-	T^1	T
Sine Vibration	T_3	T_3	T_3
Mechanical Shock	T	T	-
Mechanical Function	A; T	T	T
Pressure Profile	A; T_1	A; T_1	-
Mass Properties	A/T	A; T	A; T_4

A-T = Analysis required and must be verified by testing. Test may be performed at Spacecraft, Spacecraft Bus, or Spacecraft hardware model level of assembly, as appropriate.
A = Analysis required.
A/T = Analysis and/or test.
A/T_2 = Analysis required; test only if dictated by analysis.
T = Test required.
T_1 = Test must be performed unless analysis and preliminary test results, e.g. frequency verification prior to modal survey testing, can be used to justify deletion.
T_3 = Test performed to simulate any sustained periodic mission environment or to satisfy other requirement (e.g., loads, shock)
T_4 = Components must be weighed.

In the absence of proof testing to 1.25 times limit loads and if Contracting Officer approval is obtained, the stress analysis method may be used for strength qualification, as follows: If appropriate development tests are performed to verify accuracy of the stress model, and stringent quality control procedures are invoked to ensure conformance of the structure to the design, then strength verification may be accomplished by a stress analysis that demonstrates that the hardware has positive margins on yield at loads equal to 2.0 times the limit load, and positive margin on ultimate at loads equal to 2.6 times the limit load. Analysis shall not be used to verify strength of elements fabricated from composite materials or from beryllium. For composites, the wider range of strength associated with composite structures must be taken into account by additional demonstrations such as development tests, proof tests and larger design factors (see also section 6.2.3). For beryllium, the property of ultimate failure without perceptible yield precludes use of analysis alone for qualification of beryllium structures.

Regardless of the qualification method used, the contractor shall analyze all flight structures as well as all test structures that are subjected to the flight hardware test environments. The analyses shall utilize design limit loads predicted for all flight and testing environments and shall include all required factors of safety. The analysis shall be performed in accordance with commonly accepted methods and assumptions and culminate with a set of Margins of Safety (M.S.) equations. Buckling, crippling, and shear failures shall be considered as ultimate failures.

CH-01 The Stress Analysis Report shall be delivered in accordance with the CDRL. The analysis shall be updated when the test-verified model is delivered. As a minimum, it shall contain the following:

a. Stress analysis results for current design limit loads, with yield and ultimate factors applied as specified above.

b. Comprehensive M.S. summary for all load cases.

The initial stress assignment shall be based on the preliminary design loads. The contractor shall keep the M.S. Summary updated as the design of the structure changes, mathematical models are refined, and/or new loads analyses are performed.

3.4.3.2 <u>Acceptance Requirements - Structural Reliability</u>.. The structural reliability requirements are intended to provide a high probability of the structural integrity of all flight hardware. The structural reliability of the Spacecraft and its elements shall be verified by a combination of the fracture control program and proof-loads testing methods to ensure that adequate residual strength (strength remaining after the flaws are accounted for) is present for structural reliability at launch.

If structural reliability is demonstrated by loads testing, any of the methods recommended in section 2.4.1.3 of the GEVS-SE may be used (i.e., static loads, acceleration, sine-burst or swept sine vibration), providing that the test adequately represents the launch loads. Where loads testing of portions of a large composite structure is used in conjunction with analysis, all portions of the structure shall be tested, and the test shall subject the members to loads stresses in modes representative of the launch environment. The test shall be performed at the component, subsystem, and spacecraft levels of assembly to the extent practicable. CH-0

For hardware that requires a fracture control program, fracture mechanics analyses and inspection shall be performed in accordance with GSFC 731-0005-83, except that safe-life parts using standard non-destructive testing (NDT) shall follow normal tracking and control procedures. Safe-life parts using special NDT shall follow the tracking and control procedures for "Fracture-Critical Parts" as defined in GSFC 731-0005-83. The combination of the methods to be used shall be generally described in the Verification Plan and shall be detailed in a Fracture Control Plan. Results of the fracture control program activities shall be documented in a Fracture Control Verification Report that shall be made to NASA upon request. CH-01

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Where the structural reliability is to be demonstrated by fracture control, the following are required:

(a) "Safe-life" or "fail-safe" analysis shall be completed on:

(1) All metal elements except beryllium that are loaded above 25% of their ultimate tensile strength, and

(2) All glass elements that are stressed above 10% of their ultimate tensile strength.

(b) "Fail-safe" analysis must be completed on:

(1) All composite elements that are loaded above 25% of their ultimate tensile strain or ultimate compressive strain, and

(2) All beryllium elements that are loaded above 25% of their ultimate tensile strength.

The Fracture Control Plan, analyses, and Fracture Control Verification Report shall, be made available to NASA upon request.

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The use of materials that are susceptible to brittle fracture or stress-corrosion cracking require development of and strict adherence to special procedures (see section 6.2.5) to prevent problems.

3.4.4 Vibroacoustics

3.4.4.1 Verification for Design Qualification. For the vibroacoustics environments, limit levels are equal to the maximum expected flight environment. The qualification level is defined as the limit plus 3 dB. When random vibration levels are determined, responses to the acoustic inputs plus the effects of vibration transmitted through the structure shall be considered. As a minimum, component random vibration levels shall be sufficient to demonstrate acceptable workmanship. For qualification of hardware, tests shall be conducted on each of three mutually perpendicular axes for the durations' indicated in Table A-1 of GEVS-SE at qualification (protoflight) levels.

3.4.4.2 Acceptance Requirements.. For the acceptance testing of previously qualified hardware, testing shall be conducted on each of three mutually perpendicular axes for the duration's indicated in Table A-1 of GEVS-SE at the maximum expected flight levels.

3.4.5 Sine Vibration

3.4.5.1 Verification for Design Qualification. Where appropriate to simulate any sustained periodic mission environment for the Spacecraft, its modular subsystems, or components, the hardware shall be subjected to sine vibration testing for the sweep rate indicated in Table A-1 of GEVS-SE to 1.25 times expected flight levels on each of three mutually perpendicular axes for design qualification.

3.4.5.2 Acceptance Requirements.. Where appropriate to simulate any sustained periodic mission environment, the acceptance testing of previously qualified Spacecraft, modular subsystems, or components shall include sine vibration testing for the sweep rate indicated in Table A-1 of GEVS-SE to expected flight levels on each of three mutually perpendicular axes.

3.4.6 Mechanical Shock

3.4.6.1 Verification for Design Qualification. Both self- induced and externally-induced shocks shall be considered in defining the mechanical shock environment. All Spacecraft subsystems shall be exposed to all self-induced shocks by actuation of the shock-producing devices. Each device must be actuated a minimum of two times in order to account for the scatter associated with different actuations of the same device.

In addition, when the most severe shock is externally induced, a suitable simulation of that shock shall be applied at the subsystem interface. When it is feasible to apply this shock with a controllable shock generating device, the verification level shall be 1.4 times the maximum expected value at the subsystem interface, and shall be applied once in each of the three axes. If it is not feasible to apply the shock with a controllable shock generating device (e.g., the subsystem is too large for the device), this test may be conducted at the Spacecraft Bus or Spacecraft level by actuation of the shock-producing devices in the elements of the Spacecraft which produce the shocks external to the subsystem to be tested. Spacecraft separation shock shall also be verified by actuation of the shock-producing devices at Spacecraft level. The shock-producing device(s) must be actuated a minimum of two times for this test.

3.4.6.2 Acceptance Requirements. Mechanical shock test requirements do not apply to the acceptance testing of previously qualified hardware if the original basis for qualification is still valid for the new application.

3.4.7 Mechanical Function

3.4.7.1 Verification for Design Qualification. A kinematic analysis of all Spacecraft mechanical operations is required to:

(a) ensure that each mechanism can perform satisfactorily and has adequate margins under worst-case conditions,

(b) ensure that satisfactory clearances exist for both the stowed and operational configurations as well as during any mechanical operation,

(c) ensure that all mechanical elements are capable of withstanding the worst-case loads that may be encountered.

In addition, verification tests are required to demonstrate that the installation of each mechanical device is correct and that no problems exist that will prevent proper operation of the mechanism during mission life.

Verification tests are required for each mechanical operation at nominal, low, and high energy levels. To establish that mechanical function is proper for normal operations, the nominal test shall be conducted at the most probable conditions predicted during normal flight. A high-energy test and a low-energy test, shall also be conducted to prove positive margins of strength and function. The levels of these tests shall demonstrate margins beyond the nominal conditions by considering adverse interaction of potential extremes of parameters such as temperature, friction, spring forces, stiffness of electrical cabling or thermal insulation, and, when applicable, spin rate. Parameters to be varied during these high- and low-energy tests shall include, to the maximum extent practicable, all those that could substantively affect the operation of the mechanism, as determined by the results of analytic predictions or development tests. As a minimum, however, successful operation at temperature extremes 10°C beyond the range of expected flight temperatures shall be demonstrated.

Mechanical functions which have been adequately tested at the subsystem level (and do not have the potential for interference with other subsystems or structure) need not be re-verified at the Spacecraft level.

3.4.7.1.1 Torque Ratio.

The torque ratio (TR) is the torque available, divided by the resistive torque. It is a measure of the degree to which the torque available to accomplish a mechanical function exceeds the torque required. TR shall be verified by testing the qualification unit both before and after exposure to qualification-level environmental testing. All TR testing shall be performed at the highest possible level of assembly, in all operating positions, and under worst-case beginning of life (BOL) environmental conditions, representing the worst-case combination of maximum and/or minimum predicted (not qualification) temperatures, gradients, voltages, and vacuum or other pertinent stress conditions. The torque ratio demonstration requirement applies to all mechanical functions, those driven by motors as well as driven by springs, at BOL only. For linear devices, the term "force" shall replace "torque" throughout this section.

The required tests are:

a. The minimum available torque of the drive system (T_{avail}) shall be verified by testing of individual motors, deployment springs, and other pertinent drive systems, in all operating positions. The measurement of available torque shall not include the mechanical advantage of harmonic drives or gear systems. Kick-off springs which do not operate over the entire range of the mechanical function shall be excluded from this test requirement. The minimum available torque shall never be less than one in-oz.

b. The maximum resistive torque of the driven system (T_{res}) shall be verified by testing of the fully assembled driven portion of the mechanism at all operating positions. For systems that include (velocity dependent) dampers, appropriate measures shall be employed to characterize (as nearly as possible) only the frictional resistive torque.

The minimum required test-verified torque ratios for various types of mechanism systems prior to environmental testing are:

System Type	Required TR_{min}
Systems which are dominated by resistive torques due to inertia, such as momentum and reaction wheels.	1.25
Systems which are dominated by resistive torques due to a combination of both inertia and friction, such as large pointing platforms and heavy deployable systems.	2.25
Systems which are dominated by resistive torques due to friction, such as deployment mechanisms, solar array drives, cable wraps, and despun platforms.	3.0

After exposure to environmental testing, the reduction (if any) in test-verified torque ratio shall be no greater than 10%, after appropriate consideration has been given to the error inherent in the test methods used to measure the torque ratio.

The required torque ratios should be appropriately higher than given above if:

> The designs involve an unusually large degree of uncertainty in the characterization of resistive torques, or
>
> The torque ratio testing is not performed in the required environmental conditions or is not repeatable, or
>
> The torque ratio testing is performed only at the component level.

For acceptance, the torque ratio shall be verified to the above-stated requirements by testing all flight units both before and after exposure to acceptance-level environmental testing. The reduction (if any) in TR shall be no greater than 10%, after exposure to environmental testing.

3.4.7.1.2 Minimum Clearance

Analyses shall be conducted to verify adequate dynamic clearances between the payload and launch vehicle, and between members within the payload for all significant ground test and flight conditions.

These analyses shall include, but not be limited to the minimum clearance under worst case conditions between any moving mechanical assembly or deployable, and any other hardware, including structure, components, thermal control materials, fasteners, cable, harness, etc., for all stowed and operational configurations, and during any mechanical operation. The manufacturing, assembly, and alignment tolerances, as well as environmental conditions, such as temperature, temperature gradients, vibration, distortion due to relaxation of the "g" field, effects of centrifugal forces, and acceleration during the critical periods of launch and on-orbit operations shall be taken into consideration in establishing clearance adequacy. Critical clearances shall be identified, the reason for the critical classification shall be explained, and activities to ameliorate possible interference's shall be tracked in a Critical Mechanical Clearance List, which shall be submitted in accordance with the CDRL. The established clearances shall be maintained during transportation and all operational modes of the spacecraft. Interface control drawings or layouts shall indicate the stowed, extended, and critical intermediate positions of the moving mechanical assemblies and deployables with respect to fields of view and surrounding structure, components, or other hardware.

The spacecraft contractor shall model and identify all critical degrees of freedom for verification of adequate minimum clearance for the following analyses, which will be performed by the launch vehicle contractor. The spacecraft contractor shall validate the results provided by the launch vehicle contractor to determine that clearances are adequate.

a. <u>During Powered Flight</u> - The coupled loads analysis shall be used to verify adequacy of clearances during flight within the launch vehicle payload fairing. One part of the coupled loads analysis output transformation matrices shall contain displacement data that will allow calculations of loss of clearance between critical extremities of the payload and adjacent surfaces of the launch vehicle. The analysis shall consider clearances between the payload and fairing (and its acoustic blankets if used, including blanket expansion due to venting) and between the payload and launch vehicle attach fitting, as applicable. For clearance calculations, the following factors shall be considered:

    1. Worst-case payload and vehicle manufacturing and assembly tolerances as derived from as-built engineering drawings.

    2. Worst-case payload/vehicle integration "stacking" tolerances related to interface mating surface parallelism, perpendicularity and concentricity, plus bolt positional tolerances, payload fairing ovality, etc.

    3. Quasi-static and dynamic flight loads, including coupled steady-state and transient sinusoidal vibration, vibro-acoustics and venting loads. Typically, either lift-off or the trans-sonic buffet and maximum airloads cause the greatest relative deflections between the vehicle and payload.

b. <u>During Launch Vehicle Payload Fairing Separation</u> - A fairing separation analysis based on ground separation test of the fairing shall be used to verify adequate clearances between separating fairing sections and payload extremities. Effects of fairing section shell-mode oscillations, fairing rocking, vehicle residual rates, transient coupled-mode oscillations, and thrust accelerations shall be considered.

c. During Payload Separation - A payload separation analysis shall be used to verify adequate clearances between the payload and the launch vehicle during separation. The analysis shall include effects of factors such as vehicle residual rates, forces and impulses imparted by the separation system (including lateral impulses due to separation clampbands) and vehicle retro-rocket plumes impinging on the payload, as applicable. The same analysis shall be used to verify acceptable payload separation velocity and tip-off rates if required.

The spacecraft contractor shall also perform analyses to verify adequacy of dynamic clearances between members within the payload during ground testing for vibration and acoustics, and during flight. Additionally, a deployment analysis shall be used to verify adequacy of clearances during payload appendage deployment.

For all the above clearance analyses and conditions, the verifications shall assume worst-case static clearances due to manufacturing, assembly, and vehicle integration tolerances (unless measured on the launch stand) and quasi-static and dynamic deflections due to 1.4 times the applicable flight limit loads or flight-level ground test levels. If the available static clearances are relatively large, the clearance analysis requirements may be satisfied in many cases by simple estimates and/or similarity.

3.4.7.2 Acceptance Requirements.. Acceptance requirements for torque ratio are stated in paragraph 3.4.7.1.1. For other mechanical functions, where it has been shown that the original basis for qualification of previously qualified hardware is valid for the new application, acceptance testing of Spacecraft mechanical operation need only demonstrate successful operation at nominal conditions and at temperatures 5°C above and below the range of predicted mission temperatures for EOS.

3.4.7.3 Life Testing. Mechanical elements that move repetitively in their normal function shall be identified and verified for adequate useful life expectancy for the mission. They shall be included in the Limited-Life List as required in section 7 of this document. Life testing methods and hardware to be used shall be described in the Verification Plan and Verification Specification. Verification of useful lifetime by analysis shall require a description of rationale (for not testing) and supporting analyses for each element that is not tested. (See also section 3.3.2.3 for life testing of electrical elements.)

3.4.8 Pressure Profile

3.4.8.1 Verification for Design Qualification. The need for a pressure profile test shall be assessed for all hardware on the Spacecraft. A verification test shall be performed if analysis does not indicate a positive margin at loads equal to twice those induced by the maximum expected pressure differential during launch and if a test was not conducted below the spacecraft level of assembly. If a test is required, the limit pressure profile is determined by the predicted pressure-time profile for the nominal trajectory of the particular mission. Because pressure-induced loads vary with the square of the rate of change, the verification pressure profile is determined by multiplying the predicted pressure rate of change by a factor of 1.12 (the square root of 1.25, the required verification factor on load).

3.4.8.2 Acceptance Requirements. Pressure profile test requirements do not apply for the acceptance testing of previously qualified hardware.

3.4.9 Mass Properties - Hardware mass property requirements are mission dependent and must be determined on a case-by-case basis. The contractor's mass properties program must include an analytic assessment of the Spacecraft's ability to comply with the mission requirements supplemented as necessary by measurement.

3.5 ELECTROMAGNETIC COMPATIBILITY (EMC) REQUIREMENTS

3.5.1 General Requirements - The general requirements for compatibility are stated below:

(a) The Spacecraft and its elements shall not generate electromagnetic interference that could adversely affect its own elements, (including the instruments) or the safety and operation of the launch vehicle and launch site.

(b) The Spacecraft, its subsystems, components, and instruments shall not be susceptible to emissions that could adversely affect their safety or performance. This applies whether the emissions are self-generated or derived from other sources, or whether they are intentional or unintentional. The requirements in this document include an assurance that the Spacecraft can operate satisfactorily within the environments usually encountered during integration and ground testing. However, some subsystems or instruments may have particularly sensitive sensors and electrical devices that are inherently susceptible to the EMI that may be expected in those ground environments; in such cases, special work-around procedures must be developed to meet these unique instrument needs.

3.5.2. Requirements Summary

3.5.2.1 The Range of Requirements.. The contractor shall develop an EMI/EMC Control analysis document to be delivered in accordance with the CDRL. The document shall establish levels reflecting the requirements of the GIRD for the respective spacecraft and the constraints placed on the Spacecraft by the launch vehicle and launch site organizations, including the launch site radiation environment. CH-01

For design qualification, the contractor shall demonstrate compliance with the general requirements of section 3.5.1 by conducting an EMC test program in accordance with Table 3-2 herein, section 2.5 of GEVS-SE, and the approved EMI/EMC Control analysis document for the respective spacecraft (see section 3.5.2.2 below). Table 3-2 prescribes tests at the Spacecraft level and lower levels of assembly. Not all tests apply to all levels of assembly. CH-01 Requirements shall be selected that fit the characteristics of the mission and hardware (e.g., a transmitter would require a different group of EMC tests than a receiver). Symbols in the hardware column will assist in the selection of an appropriate EMC test program.

Table 3-2 EMC Requirements per Level of Assembly

Type	Test	GEVS-SE Para. #	Spacecraft/ Spacecraft Bus(*)	Subsystem	Component
CE	DC power leads	2.5.2.1a	-	R	R
		2.5.2.1b	-	R	R
			-		
CE	Antenna terminals	2.5.2.1e	-		R
RE	AC magnetic field	2.5.2.2b	R	R	R
RE	E-fields	2.5.2.2c	R	R	R
		2.5.2.2d	R	R	R
RE	Payload xmitters	2.5.2.2e	***	-	-
RE	Spurious: xmitter antenna	2.5.2.2f		R	R
CS	Power line & transients	2.5.3.1a	-	R	R
		2.5.3.1e	-	R	R
CS	Intermodulation Products	2.5.3.1b	-	R	R
CS	Signal rejection	2.5.3.1c	-	R	R
CS	Cross modulation	2.5.3.1d	-	R	R
RS	E-field (general)	2.5.3.2a	R	R	R
RS	Magnetic field Susceptibility	2.5.3.2d	R	R	R
	Magnetic properties	2.5.4	R	R	R

CE - Conducted Emission
CS - Conducted Susceptibility
R - Test to ensure reliable operation of hardware, and to help ensure compatibility with the rest of the Spacecraft, the ELV and launch site.
RE - Radiated Emission
RS - Radiated Susceptibility
* - Spacecraft, Spacecraft Bus, or highest level of assembly
*** - Must meet any unique requirements of the ELV and launch site for transmitters that are on during launch.

3.5.2.2 Basis of the Tests. A description of the individual EMC tests listed in Table 3-2, including their nominal limits and test procedures, is provided in the GEVS-SE. The specific limits (levels) shall be as defined in the approved EMI/EMC Control analysis document for the respective Spacecraft. The tests and their limits may be revised as appropriate for a particular component, subsystem, instrument or mission if COTR approval is obtained. More stringent requirements may be necessary, as for example for a subsystem or instrument with very sensitive electric field or magnetic field measurements. The sequence of the EMI/EMC tests relative to the other environmental tests is optional except that magnetics tests shall not be done until all vibration testing is complete. The tests and their limits shall be documented in the Verification Specification (see section 3.2.2). CH-01

3.5.3 Flight Acceptance. The EMI/EMC qualification test program (see section 3.5.2) shall be imposed on all flight hardware to detect workmanship defects and unit-to-unit variations.

3.6 VACUUM, THERMAL, AND HUMIDITY REQUIREMENTS

3.6.1 General Requirements - The following Spacecraft capabilities (or capabilities of elements of the Spacecraft) shall be demonstrated to satisfy requirements in the vacuum, thermal, and humidity areas:

(a) The Spacecraft shall perform satisfactorily in the vacuum and thermal environment of space.

(b) The thermal design and the thermal control subsystem shall maintain the affected hardware within the established mission thermal limits.

(c) The hardware shall withstand, as necessary, the temperature and humidity conditions of fabrication, assembly, transportation, storage, and launch.

3.6.2 Summary of Requirements - Table 3-3 summarizes the tests and analyses that collectively will serve to fulfill the general requirements of section 3.6.1. Tests noted in the Table 3-3 may require supporting analyses and vice versa. The order in which demonstrations are conducted shall be determined by the contractor and specified in the Verification Plan (see section 3.2.1).

3.6.3 Thermal-Vacuum

3.6.3.1 General Requirements. The thermal-vacuum test shall demonstrate the ability of the Spacecraft and its elements to perform satisfactorily in functional modes representative of the mission in vacuum at the nominal mission operating temperatures, at temperatures 10°C beyond the predicted mission extremes, and during temperature transitions. The test shall also demonstrate the ability of the Spacecraft to perform satisfactorily after being exposed to the predicted non-operating temperature limits of the mission, including the 10°C margin.

Cold and hot turn-ons shall be demonstrated where applicable. The ability to function through the voltage breakdown region, if applicable, shall be demonstrated.

Components shall be subjected to a minimum of 12 thermal-vacuum cycles, at least four of which shall be at the Spacecraft level. The complete Spacecraft shall be subjected to a minimum of four thermal-vacuum cycles (see Table 3-3 for details, including cycles for modular subsystems). For components that are not sensitive to vacuum, the component-level thermal cycling tests may be conducted in air or in gaseous nitrogen environment at atmospheric pressure if prior approval of the Contracting Officer is obtained; if testing is conducted in air, the number of cycles shall be increased to 15, and the qualification test temperature range shall be broadened to 15°C beyond each of the predicted mission extremes.

During any thermal-vacuum cycling, the rate of temperature change shall not exceed 5°C. per hour or the maximum allowable rate of temperature change, whichever is higher. Components and subsystems shall be soaked for a minimum of four hours after temperature stabilization (see Appendix B) at each hot and cold temperature extreme of each cycle. During thermal-vacuum testing at the Spacecraft level, the Spacecraft shall be soaked for a minimum of sixteen hours after stabilization at each temperature extreme of each cycle. The contractor shall state in the Verification Plan (see section 3.2.1) the proposed testing scenario for the Spacecraft and its components.

The hardware at all levels of assembly shall be operated and its performance monitored throughout the test. Redundant hardware elements shall be exercised insofar as practicable to verify the functioning of all redundant paths. At the Spacecraft level, turn-on capability shall be demonstrated at least twice during the low temperature extreme (defined as 2°C below the low survival temperature for the Spacecraft) survival demonstration and at least twice during the high temperature extreme (defined as 2°C above the high survival temperature for the Spacecraft) survival demonstration. Turn-on demonstrations require that the hardware must function, but performance within specification is not required until the hardware reaches the qualification or acceptance operating range, as appropriate. The ability to function through the voltage breakdown region, if applicable, shall be demonstrated.

Table 3-3 Vacuum, Thermal, and Humidity Requirements

Requirement	Spacecraft or Highest Practical Level of Assembly	Modular Subsystem	Component*
Thermal-Vacuum	T4	T2	T8
Thermal Balance	A & T	A	A
Temperature-Humidity (Transportation & Storage)	A	A	A
Leakage1		T3	T3

1 = Hardware that passes this test at a lower level of assembly need not be retested at a higher level unless there is reason to suspect its integrity.

T3 = Test required for sealed hardware units, only.

A = Analysis required; tests may be required to substantiate the analysis.

A & T = An analysis is required to develop a mathematical model; this shall be verified by test.

* = Components of the Spacecraft Bus.

T4 = 4 T-V cycles required for spacecraft.

T2 = 4 T-V cycles required for modular subsystems having discrete components. 8 T-V cycles required if subsystem does not have discrete components.

T8 = 8 T-V cycles (total) required for components before integration on spacecraft. 4 of these may be at subsystem level T-V test.

Temperature excursions during the cycling of components shall be sufficiently large to detect latent defects in workmanship. Cold and hot turn-on capability shall be demonstrated as part of the thermal-vacuum testing at the component level, whenever appropriate.

Outgassing procedures that are found necessary (see section 9) shall be made part of the thermal-vacuum test operations if no unacceptable hazards are introduced by these procedures.

3.6.3.2 Acceptance Requirements. For the acceptance testing of previously qualified hardware, testing shall be conducted at temperatures 5°C beyond the predicted mission extremes.

3.6.4 Thermal Balance

3.6.4.1 Verification for Design Qualification. This verification shall demonstrate the validity of the thermal design and the ability of the thermal control subsystem to maintain the Spacecraft within the established thermal limits for the mission. The analytical thermal model shall be validated by tests. The tests may be conducted as necessary on selected components and on a (hardware) thermal model of the Spacecraft, or on the Spacecraft. The capability of the thermal control system shall be demonstrated in the same manner. If the flight hardware is not used in the test of the control subsystem, verification of critical thermal properties (e.g., those of the thermal control coatings) shall be performed to demonstrate similarity between the item tested and the flight hardware. Prior to the test, the power dissipation and line losses of individual components shall be measured to an accuracy of 1%, where feasible. Verification of the thermal design is considered accomplished if the differences between the predicted and measured temperatures fall within the established allowable temperature differences and if the margins defined in the approved Project requirements document for the Spacecraft are demonstrated. Heat rejection margin can be demonstrated by hot case temperature results, which are lower than the maximum allowable design temperatures. The thermal testing shall include demonstration that the design provides positive heater power margins (duty cycles) and adequate thermostat control (open and close points).

Thermal balance verification requires use of analytical thermal models to:

(a) demonstrate the validity of the payload instruments' and Spacecraft thermal designs,

(b) predict the Spacecraft's mission thermal performance, and

(c) predict thermal balance test performance.

The thermal balance test predictions shall be derived from the modified flight analytical models. The modifications shall reflect the actual test conditions.

3.6.4.2 Acceptance Requirements. The thermal balance verification may be waived if the protoflight hardware was subjected to thermal balance testing, and in the case of previously qualified hardware if there is valid similarity between the new and original applications. Analyses/tests shall be conducted to verify the thermal similarity of the two applications. Otherwise, a thermal balance test shall be conducted on the flight hardware at the expected mission conditions.

3.6.5 Temperature-Humidity: Integration, Checkout, Transportation, and Storage

3.6.5.1 Verification for Design Qualification. Analysis and, when necessary, test shall demonstrate that flight hardware that is not maintained in a controlled temperature-humidity environment to within demonstrated acceptable limits will perform satisfactorily after exposure to the uncontrolled environment.

The test shall include exposure of the hardware to the extremes of temperatures and humidity as follows: 10°C and 10% relative humidity (RH) (but not greater than 95% RH) higher and lower than those predicted for the transportation and storage environments. Temperature levels, R.H. levels and rates of change during testing shall be controlled to prevent condensation unless this is representative of environments to which the hardware will be exposed prior to use. The exposure at each extreme shall be for a period of six hours.

3.6.5.2 Acceptance Requirements. The 10°C temperature margin and the 10% RH margin may be waived for previously qualified hardware.

3.6.6 Leakage - This test shall demonstrate that leakage rates of sealed hardware units are within the prescribed mission limits (for both qualification and acceptance testing). Leakage rates shall be checked once early in the test sequence, and a final check shall be conducted after the final thermal-vacuum test at the subsystem or component level. Additional leak checks may be made optionally, before and after any parts of the verification program considered to induce especially high stresses that may compromise the integrity of leak-sensitive hardware.

Checks at the subsystem level need include only those items that have not been leak tested at the component level or are not fully assembled until this higher level of integration.

3.7 END-TO-END TEST REQUIREMENTS

3.7.1 Compatibility Test - An end-to-end compatibility test shall be conducted using all portions of the operational system; namely, the Spacecraft, the operational software, and the ground system, including the EOS Operations Center (EOC), and the appropriate network elements in order to fully demonstrate operational compatibility so that the entire system will perform as required for the mission. When acceptable simulation facilities are available for portions of the operational system they may be substituted for the actual system element.

3.7.2 Mission Simulations - Data flow tests shall be performed utilizing the total system in a realistic mission timeline, including external stimulus of the instruments and attitude control sensors, when practicable.

Telemetry and command demonstrations shall be conducted, incorporating all the required equipment: e.g., appropriate Network elements, ECOM, EDOS, EOC, Instrument Control Facility (ICF), data processing facilities, and, when available, the users' Instrument Support Terminals. Once the data flow paths have been verified, mission simulations shall be held to validate nominal and contingency mission operating procedures and to provide for operator familiarization training. It is essential that instrument developers be included in mission simulations in order to provide ample time for checkout of their EOC software and hardware configurations.

Attachment C

Reference Document List

NASA-STD-8739.3: Soldered Electrical Connections
NASA-STD-8739.4: Crimping, Interconnecting Cables, Harnesses, and Wiring

NAS 5300.4(3J-1): Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies

NASA-STD-8739.7: Electrostatic Discharge Control (Excluding Electrically Initiated Explosive Devices)

NAS 5300.4 (3M): Workmanship Standard for Surface Mount Technology

EWR 127-1: Eastern and Western Range Safety Requirements (T)
GSFC PPL-21: Goddard Space Flight Center Preferred Parts List, may 1996
MIL-STD-975: NASA Standard EEE Part List
GSFC 311-INST-001: Instructions for EEE Parts Selection, Screening, and Qualification
GSFC S-311-M-70: Specification for Destructive Physical Analysis (DPA)
Mil-Std-882C: Systems Safety Program Requirements
NASA Reference Publication 1124: Outgassing Data for Selecting Spacecraft Materials
ESA RD-01, Revision 3: Outgassing and Thermo-optical Data for Spacecraft Materials
ECSS-Q-30A: Dependability
GSFC 422-11-12-01: GSFC General Instruments Requirements Document
GSFC 420-05-04: Performance Assurance Requirements for EOS Common Spacecraft
ECSS –Q-80A: Software Product Assurance
NSS 1740.13: Software Safety Standard
NASA Technical Memorandum 4322: Reliability Preferred Practices For Design And Test
PSS-01-201: Contamination and Cleanliness Control
X-900-93-02: EOS Common Spacecraft Radiation Environment

Attachment D

Acronym List

CCR	Configuration Change Request
CDR	Critical Design Review
CND	Could-Not-Duplicates
CPT	Comprehensive Performance Test
CPU	Central Processing Unit
DRL	Data Requirements List
EEE	Electrical, Electronic, and Electro-mechanical parts
EMI/EMC	Electromagnetic Interference/Electromagnetic Compatibility
FMEA	Failure Modes and Effects Analyses
FMI	Finnish Meteorological Institute
FOR	Flight Operations Review
GIRD	General Interface Requirement document for EOS common Spacecraft
GSFC	Goddard Space Flight Center
ICD	Interface Control Document
IOC	Initial Operational Capacity
KNMI	Royal Netherlands Meteorological Institute
L&EO	Launch & Early Operations
LS	Lead Scientist
LPT	Limited Performance Test
LRR	Launch Readiness Review
MAR	Mission Assurance Requirements
MSPSP	Missile System Prelaunch Safety Package
MOR	Mission Operations Review
NASA	National Aeronautical & Space Administration
NIVR	Netherlands Agency for Aerospace Programs
OHA	Operational Hazard Analyses
OMI	Ozone Monitoring Instrument
OSSMA	Office of Systems Safety and Mission Assurance
OIT	OMI Industrial Team
OPMO OMI	Programme Management Office
PAR	Performance Assurance Requirements
PDR	Preliminary Design Review
PER	Pre-Environmental Review
PHA	Preliminary Hazard Analyses
POCC	Payload Operations Control Center
PSR	Pre-Ship Review
RID	Review Item Discrepancy
RF	Radio Frequency
RFA	Request for Action
SHA/SSHA	System/Subsystem Hazard Analyses

SNR	Safety Noncompliance Request
SCM	Software Configuration Management
SCR	System Concept Review
SRO	Systems Review Office
TDRP	Technical Design Review Program
UIID	Unique Instrument Interface Document